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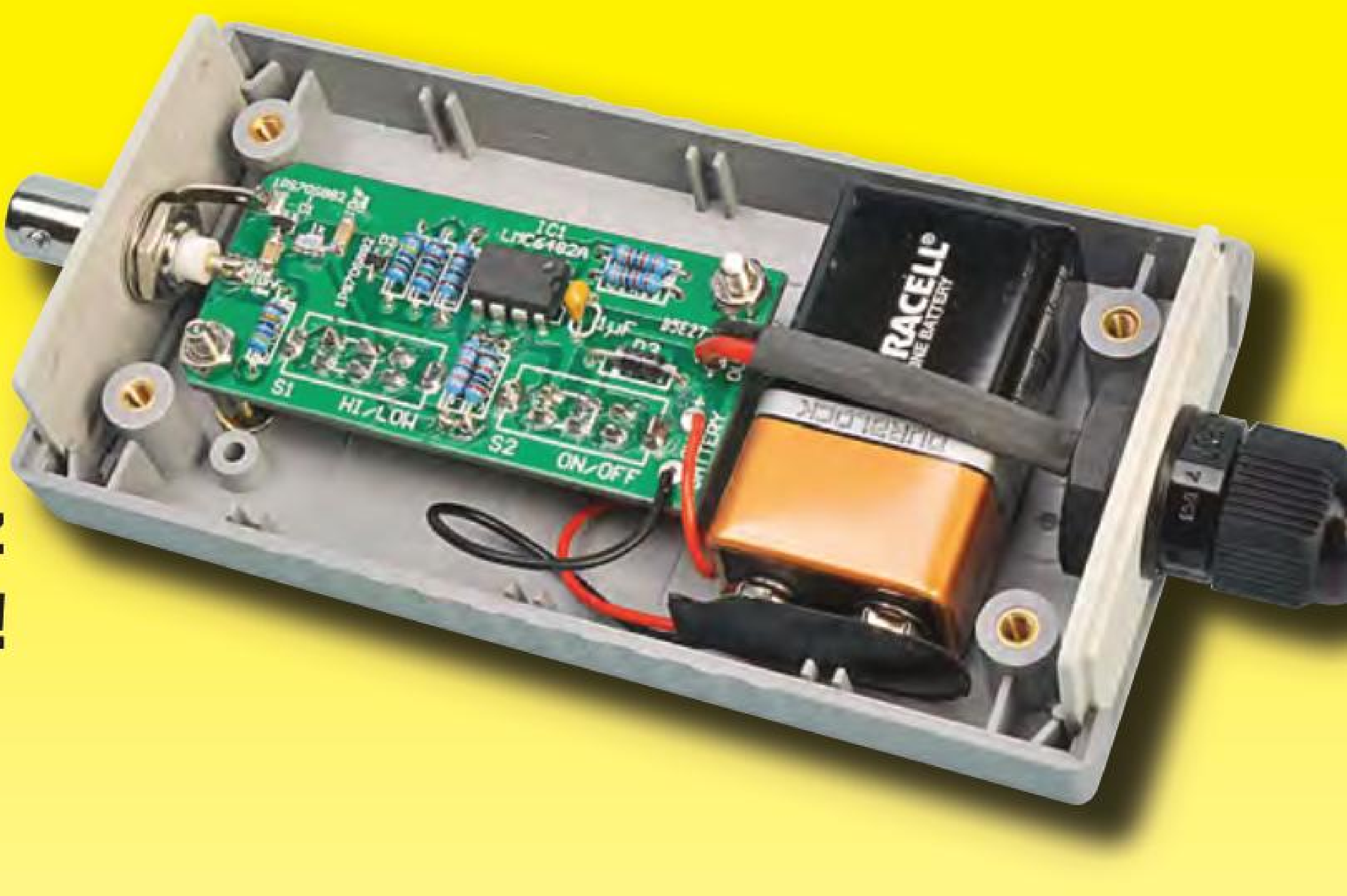

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For signals from 100kHz to over 1GHz
Battery powered – portable and safe!
Detects from 20mV up to 10V RMS
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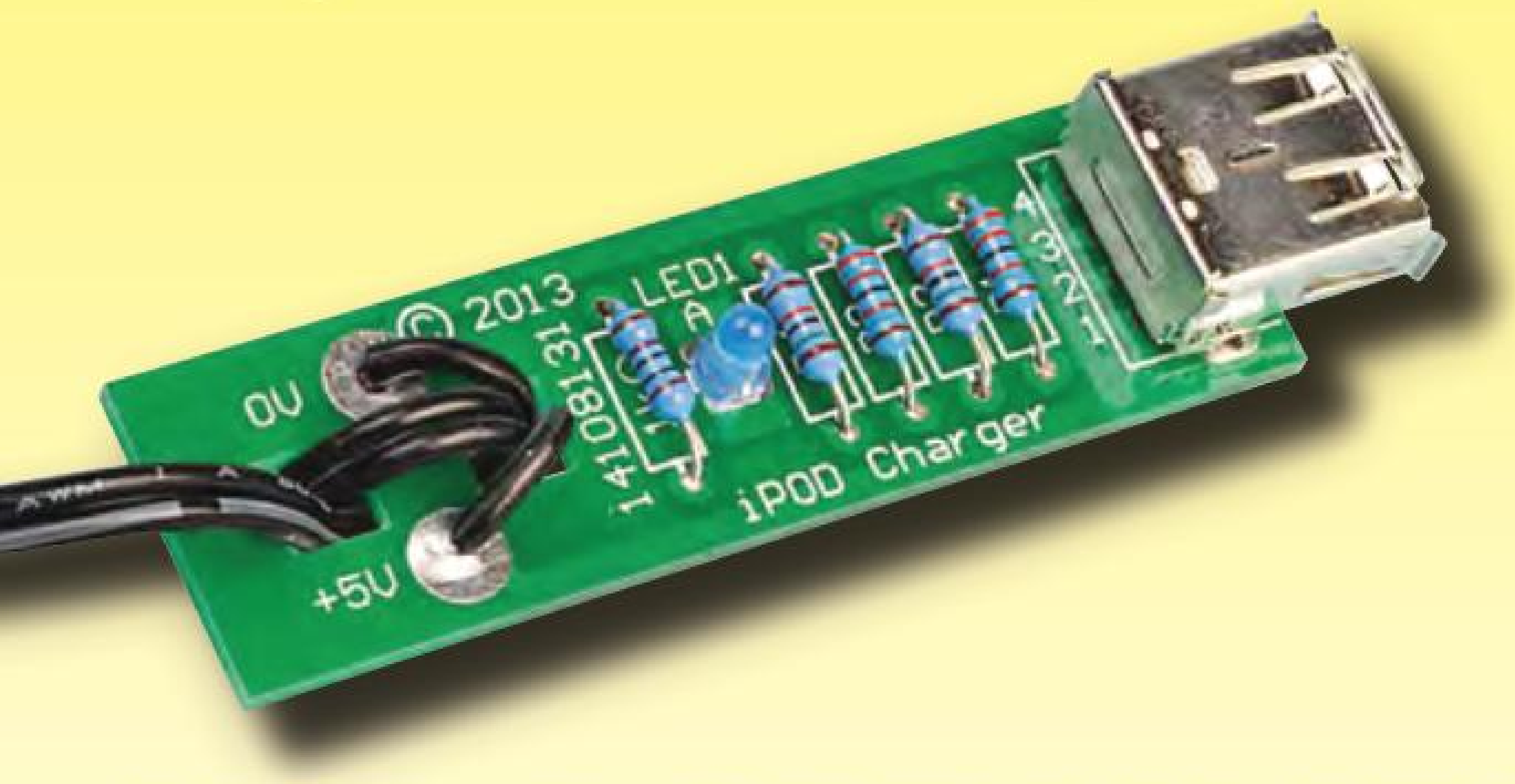
Easy to calculate power



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80
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51
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Low Sleep Currents with Flexible Wake-up Sources

- Sleep current down to 9 nA
- Brown-Out Reset down to 45 nA
- Real-Time Clock down to 400 nA

Low Dynamic Currents

- As low as 30 µA/MHz
- Power-efficient execution

Large Portfolio of XLP MCUs

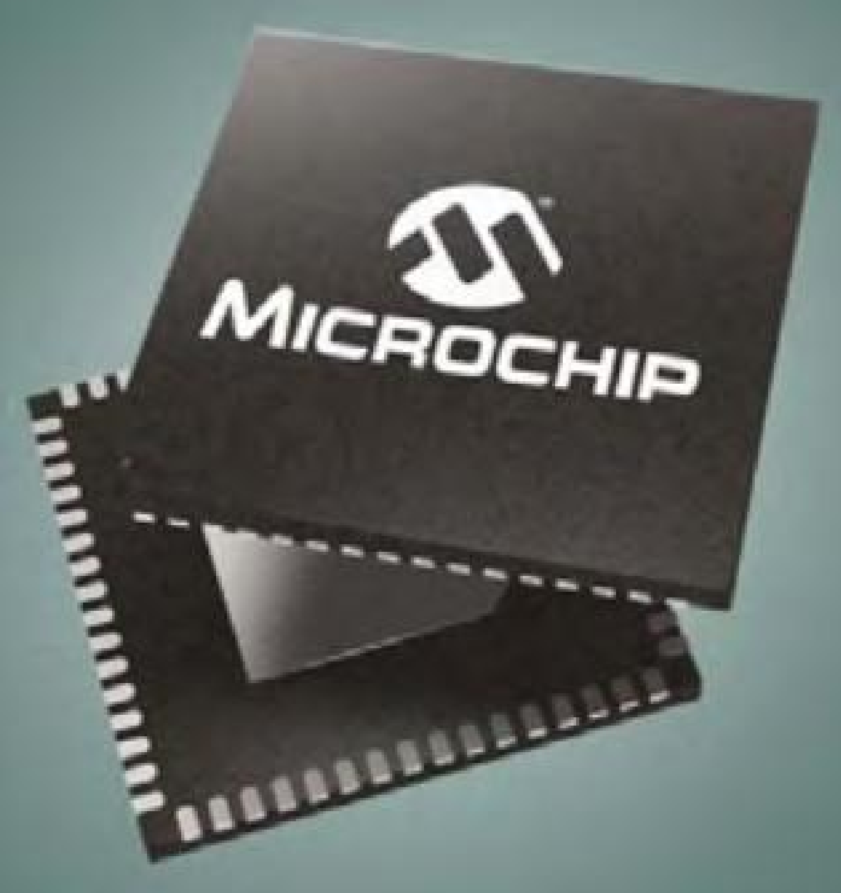
- 8–100 pins, 4–128 KB Flash
- Wide selection of packages, including chip scale packages

Battery-Friendly Features

- Enable battery lifetime > 20 years
- Operate down to 1.8V with self write and analog functions
- Low-power supervisors for safe operation (BOR, WDT)

Flexible Peripheral Set

- Integrated USB, LCD, RTC and touch sensing
- Eliminates costly external components



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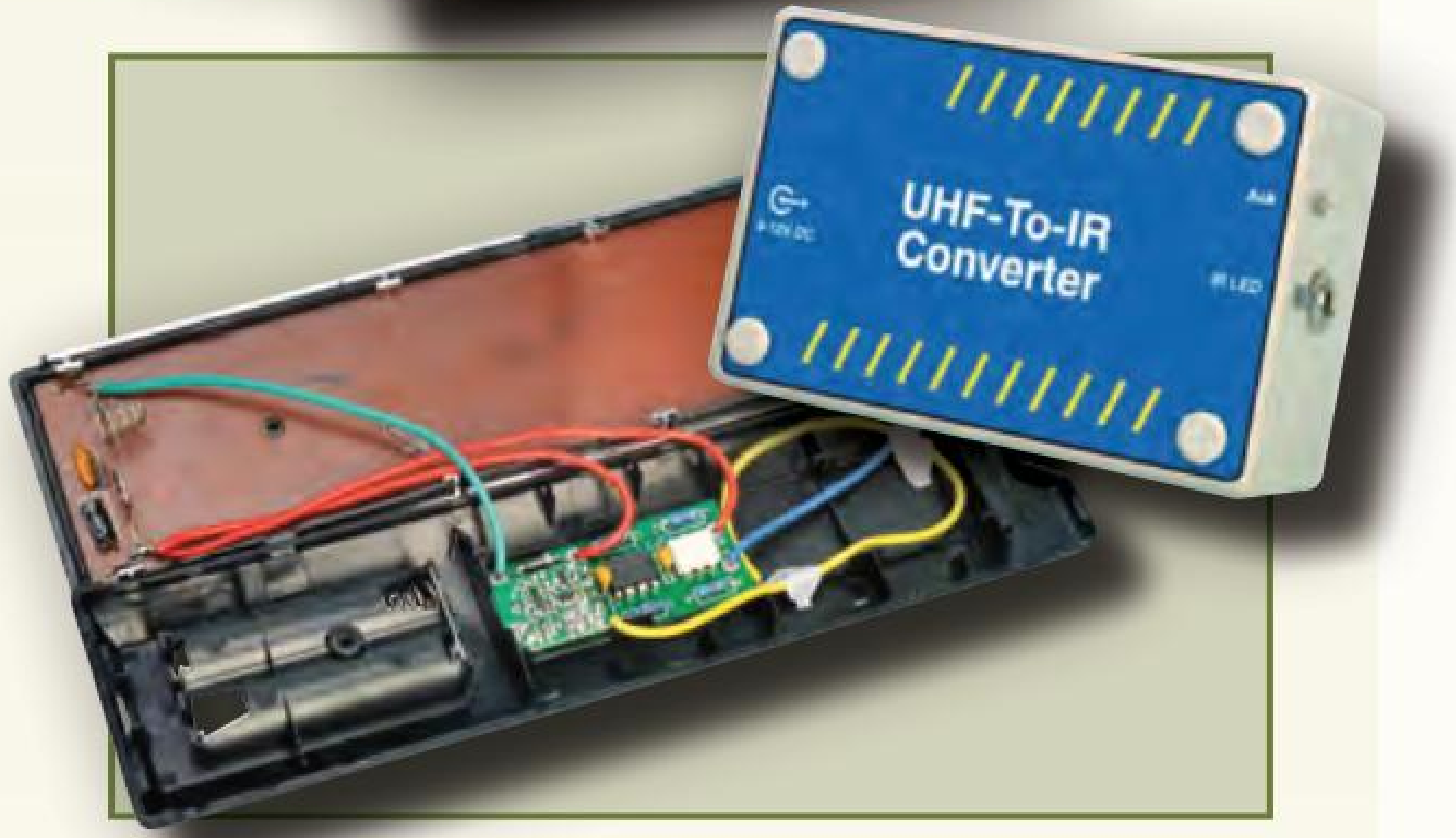

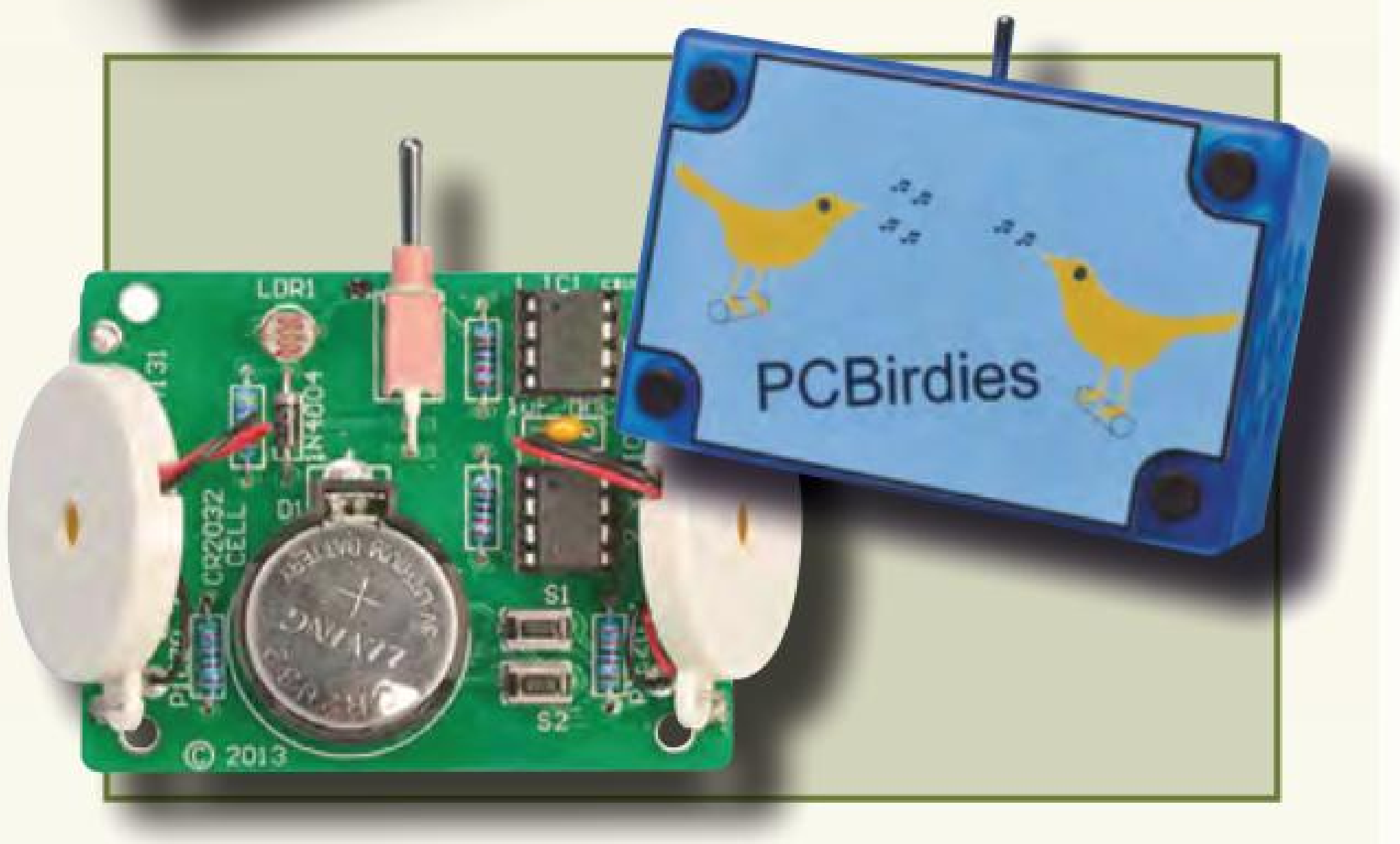

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Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

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Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
*Kit Order Code: 3179KT - **£17.95***
*Assembled Order Code: AS3179 - **£24.95***

Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
*Kit Order Code: 3158KT - **£24.95***
*Assembled Order Code: AS3158 - **£34.95***

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
*Kit Order Code: 3166v2KT - **£23.95***
*Assembled Order Code: AS3166v2 - **£33.95***

DC Motor Speed Controller (100V, 7.5A)

Control the speed of almost any common DC motor rated up to 100V, 7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
*Kit Order Code: 3067KT - **£19.95***
*Assembled Order Code: AS3067 - **£27.95***

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code 660.446UK £11.52

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Plastic case included. 130x100x30mm. Power: 12Vdc/500mA.
*Kit Order Code: 3108KT - **£74.95***
*Assembled Order Code: AS3108 - **£89.95***

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
*Kit Order Code: 3145KT - **£19.95***
*Assembled Order Code: AS3145 - **£26.95***
*Additional DS1820 Sensors - **£4.95 each***

2-Channel High Current UHF RC Set

State-of-the-art high security. 2 channel. Momentary or latching relay output rated to switch up to 240Vac @ 10 Amps. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 3 indicator LEDs. Rx: PCB 88x60mm, supply 9-15Vdc.
*Kit Order Code: 8157KT - **£49.95***
*Assembled Order Code: AS8157 - **£54.95***

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
*Kit Order Code: 3140KT - **£79.95***
*Assembled Order Code: AS3140 - **£94.95***

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
*Kit Order Code: 3142KT - **£64.95***
*Assembled Order Code: AS3142 - **£74.95***

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller. Four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay outputs are independent of sensor channels allowing flexibility to setup the linkage in any way you choose. Simple text string commands for reading temperature and relay control via RS232 using a comms program like Windows HyperTerminal or our free Windows application.
*Kit Order Code: 3190KT - **£84.95***
*Assembled Order Code: AS3190 - **£99.95***

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USB & Serial Port PIC Programmer

USB or Serial connection. Header cable for ICSP. Free Windows software. See website for PICs supported. ZIF Socket & USB lead extra. 16-18Vdc.
Kit Order Code: 3149EKT - £49.95
Assembled Order Code: AS3149E - £64.95
Assembled with ZIF socket Order Code: AS3149EZIF - £74.95

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. 16Vdc.
*Kit Order Code: 3123KT - **£28.95***
*Assembled Order Code: AS3123 - **£39.95***

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PROJECTS • 6-Decade Capacitance Substitution Box • Soft Starter For Power Tools • High Power Brushless Motors From Old CD/DVD Drives • High-Current Adaptor For Scopes And DMMs

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FEATURES • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 1

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PROJECTS • Digital Sound Effects Module • USB Stereo Recording & Playback Interface • Vacuum Pump From Junk • Minireg 1.3-22V Adjustable Regulator • Ingenuity Unlimited

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PROJECTS • LED Musicolour – Part 1 • High-Temperature Thermometer/Thermostat • Ingenuity Unlimited

FEATURES • Teach-In 2014 – Part 1 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • Computer Error: Reliable Digital Processing – Part 3

NOV '13

PROJECTS • CLASSiC-D Amplifier – Part 1 • LED Musicolour – Part 2 • Mains Timer For Fans Or Lights • Ingenuity Unlimited

FEATURES • Teach-In 2014 – Part 2 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work

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PROJECTS • Six Test Instruments In One Tiny Box • Virtins Technology Multi-Instrument 3.2 • CLASSiC-D Amplifier – Part 2 •

FEATURES • Teach-In 2014 – Part 3 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work

JAN '14

PROJECTS • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 1 • The Champion Amplifier • Simple 1.5A Switching Regulator •

FEATURES • Teach-In 2014 – Part 4 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

FEB '14

PROJECTS • High-energy Electronic Ignition System – Part 1 • Mobile Phone Loud Ringer! • 2.5GHz 12-Digit Frequency Counter With Add-on GPS Accuracy – Part 2

FEATURES • Teach-In 2014 – Part 5 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

MAR '14

PROJECTS • Infrasound Detector • Extremely Accurate GPS 1pps Timebase For A Frequency Counter • High-energy Electronic Ignition System – Part 2 • Automatic Points Controller For Your Model Railway Layout

FEATURES • Teach-In 2014 – Part 6 • Techno Talk • Circuit Surgery • Practically Speaking • Max's Cool Beans • Net Work • PIC N' Mix • Net Work

APR '14

PROJECTS • Jacobs Ladder • Deluxe GPS 1pps Timebase For Frequency Counters • Capacitor Discharge Unit For Twin-Coil Points Motors

FEATURES • Teach-In 2014 – Part 7 • Techno Talk • Circuit Surgery • Interface • Max's Cool Beans • Net Work • PIC N' Mix • Net Work • Beta-Layout's Re-Flow Oven Kit And Controller review

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PROJECTS • Rugged Battery Charger • CLASSiC-D ±35V DC-DC Converter • Digital Multimeter Auto Power-Down • Control Relays Over The Internet With Arduino

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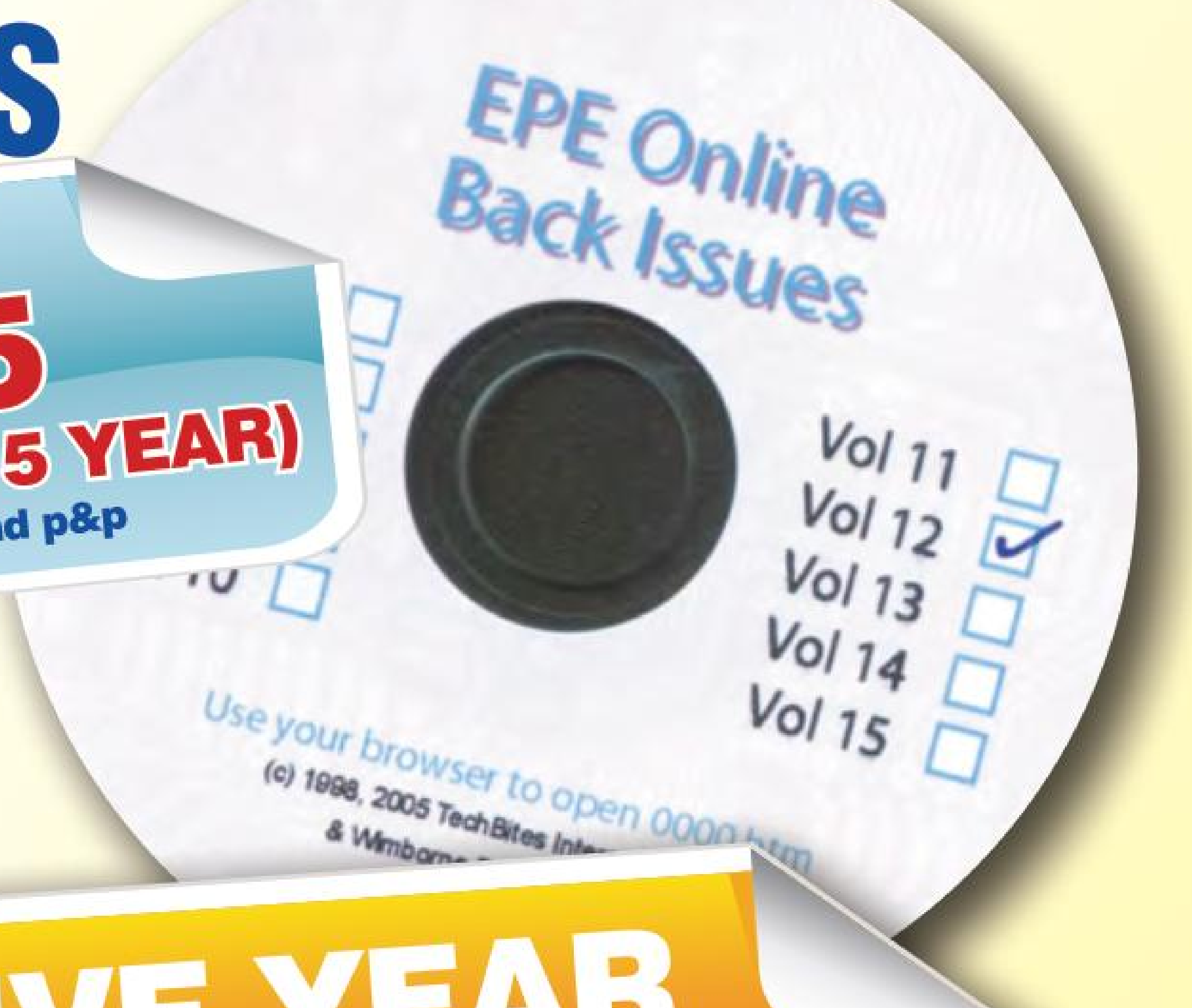
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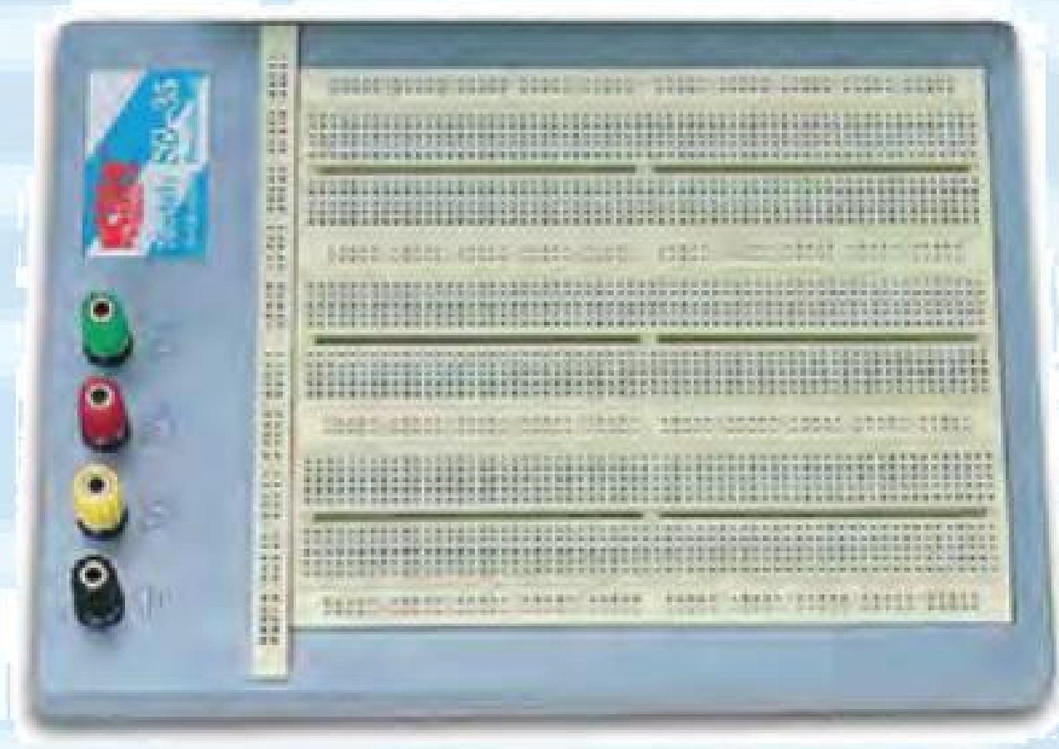

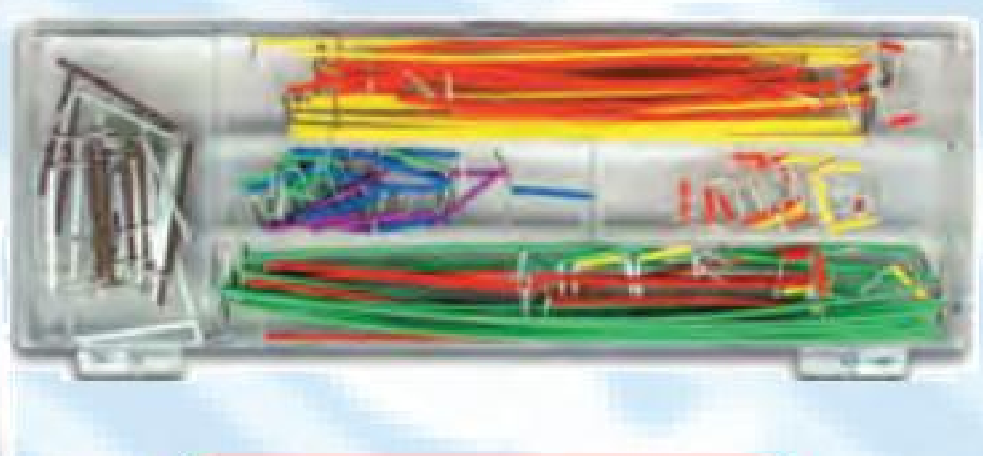

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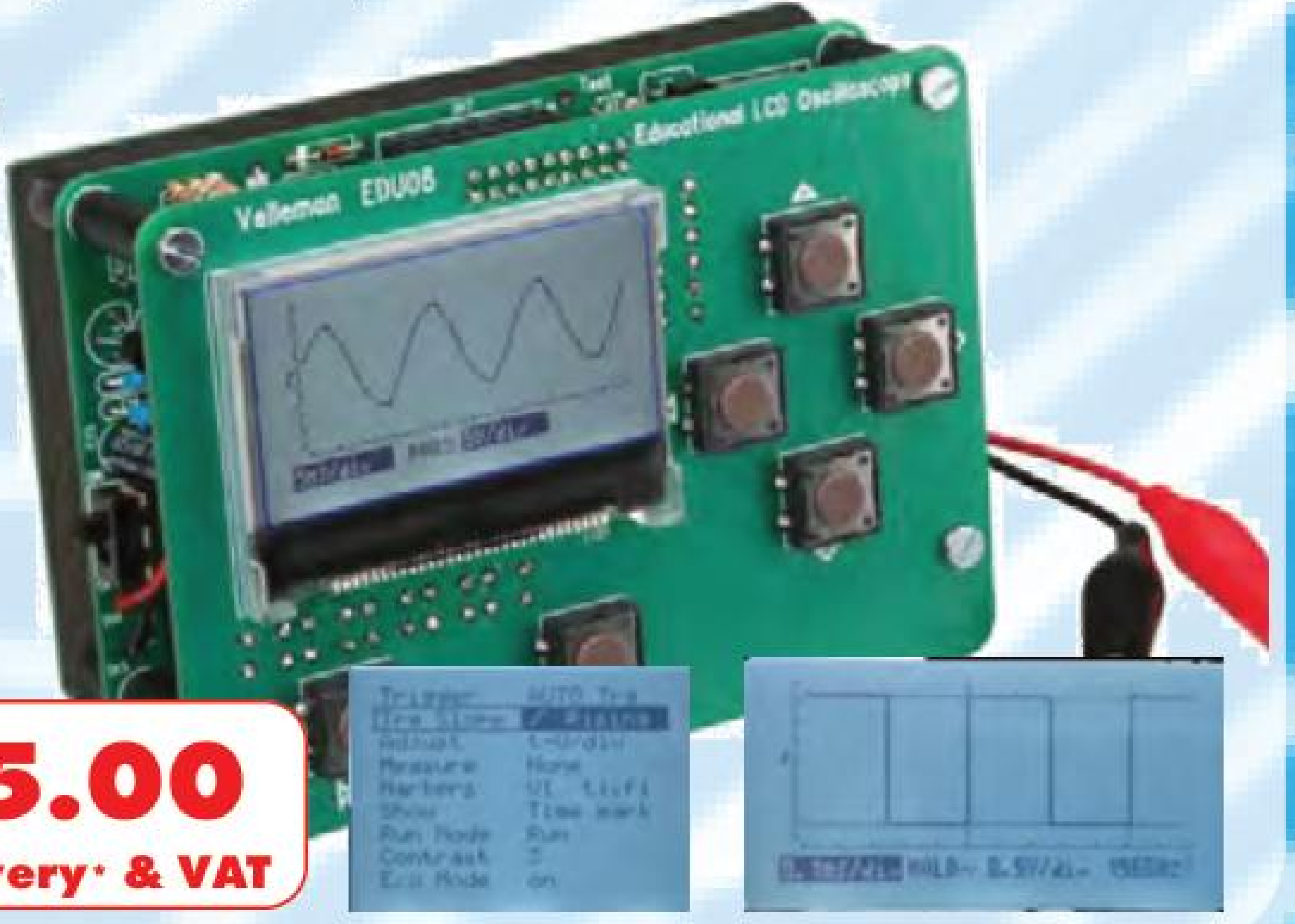

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VOL. 43 No. 08 AUGUST 2014

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EPE EVERYDAY PRACTICAL ELECTRONICS

Why?

I like to think I am reasonably well informed about most physical phenomena, especially those relating to electricity and electronics. Some of my knowledge is wide, but somewhat shallow, other areas have greater depth thanks to work or a specific interest. For example, while I may not carry around in my head *all* the finer details relating to thyristor or three-phase transformer operation, I do know roughly what happens and I know where to go if I need specific information.

I was musing recently about simple electric motors and I began to realise I didn't actually know something incredibly basic – why do current-carrying wires repel or attract each other. Of course, I know about magnetic fields and the fields produced by currents in wires, but that didn't seem to be enough information to describe the cause of these phenomena – it was just a description. At a fundamental level, why do parallel moving charges attract or push each other away, and why should they care in which direction they are travelling relative to each other?

Special relativity

This started to bug me, and so – inevitably – I Googled the topic. Up popped a rather good video on YouTube, see: **http://youtu.be/1TKSfAkWWN0**

The answer was most surprising (to me) – it's all due to special relativity; yes, Einstein's special relativity. Strictly speaking the video doesn't discuss parallel wires, but if you think (very hard in my case) about what an electron 'sees', then you can work out the correct repulsive and attractive effects. Why did this surprise me? Well, for three main reasons:

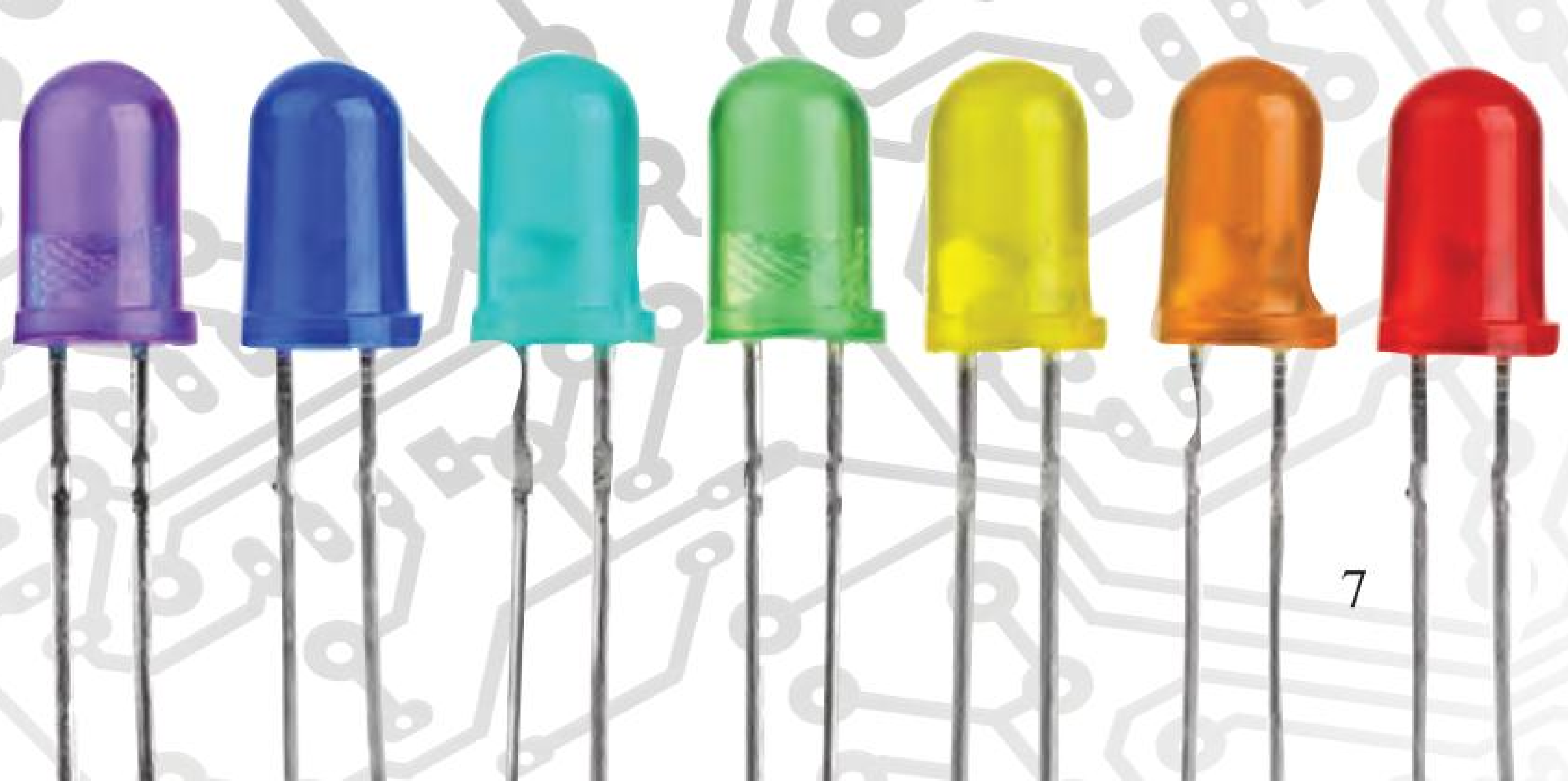
First, I had never heard of a relationship between special relativity and the forces between current-carrying wires. Having gone through GCSE and 'A' mathematics and physics, followed by an engineering degree, plus a great interest in science writing and documentaries, I am amazed I had never come across this pretty basic fact.

Second, it meant Ampère, Maxwell, Faraday and all the other great 19th century scientists didn't know why wires behave as they do – Einstein published his theory in 1905.

Third, and perhaps most intriguing of all, I usually associate effects due to special relativity with bodies travelling near the speed of light. However, the charges in a current-carrying wire actually move at 'human-scale' speeds; speeds we could just about see if electrons were visible. I say 'just about' not because their speed is so fast, quite the opposite, it is very slow – perhaps a few millimetres per hour.

I did wonder if I was alone in my ignorance, and asked a few informed people if they knew about it; the only person who did – surprise, surprise – was a physicist.

It just goes to show, even with the most basic things in science and engineering, there is always something new and fascinating to learn. Do watch the video, it is both interesting and entertaining.



NEWS

A roundup of the latest Everyday News from the world of electronics

Protecting 4k standards in Europe – report by Barry Fox

In the early days of flat screen TV, consumers were befuddled by the difference between SD, HD, HD-Ready, Full HD and Freeview HD sets, with and without the HDMI inputs needed for connecting external HD players, receivers and accessories. The television industry wants to try and avoid a re-run of this consumer confusion, with 4k or Ultra HD.

Protected logos

New logos are in the pipeline, intended to protect consumers from manufacturers who try to palm off TVs that have no 4k connection and just roughly upscale HD material, sometimes to less than full 4k resolution. The HDMI 2.0 logo offers consumers no such protection because it defines only connection options and cannot be used as a marketing label.

Digital Europe

The European UHD logo work is being done by Brussels-based group Digital Europe, which in 2009 replaced EICTA, the European Information & Communications Technology Industry Association, which created the European HD Ready logo in 2005.

Digital Europe represents all the major manufacturers active in the European market and started work on a 4k logo standard in June 2013. Mark Londero, Technology Planning manager for Sony Home Entertainment Europe, explained the latest developments shortly after a recent Digital Europe meeting.

At least two logos, based on the phrases Ultra HD Display and Ultra HD 2160p, will be legally registered by Digital Europe as Trade Marks, Their use will only be permitted for products that meet a clearly defined minimum technical specification.

Technology minima

The display screen must have a minimum resolution of 3840 × 2160 pixels and 16:9 aspect ratio, with connectors that support HDMI 2.0 and HDCP 2.2.

Colour gamut is BT 709 (ITU-R Recommendation BT.709, or Rec. 709), with a minimum of 8-bit coding, 4:2:0 colour coding and frame rates 24, 25, 30, 50 or 60p.

These minima will block the sale of TVs that have only old HDMI 1.4 connectors, but will permit the sale of sets which exceed the basic specification, for instance by using a display with a Digital Cinema screen resolution of 4096 × 2160 pixels or a '5k' super wide screen with 64:27 aspect ratio.

Progress towards a logo was delayed when the German authorities blocked Toshiba's attempt to register the logo Ultra HD, and Belgium blocked Digital Europe's attempt on the grounds that it was just a pair of words. The new logos combine words and artistic get-up. Final group approval was targeted for mid-May, with trademark registration at the end of June and licensing to begin by mid-July.

Ready by Christmas?

'But as with all things legal, dates can slip' Mark Londero told me at Sony's European HQ at Weybridge, near London. 'Speaking personally, I don't expect logos to be visible in the market until the pre-Christmas period.'

There are 'no plans' to use an additional logo similar to that now being used in Japan, '4k/60p'. But there may be other logos based on the Ultra HD theme. Although Digital Europe is concerned only with marketing in Europe, the logos will be protected outside Europe.

'Like the HD Ready logo, the Ultra HD logos are about connection, to protect people against sets with no external 4k connectivity, and also to pre-empt low cost panels that are described as 4k but use alternative pixel arrangements, such as red, green, blue, white, to deliver sub-4k resolution' Londero explained.

Sharp practice?

Interestingly, Sharp has just launched a TV with extra (yellow) colour sub-pixels, and claims that it is the 'only FHD TV on the market able to display UHD (4k) native content in effectively UHD resolution.' (see: **www.sharp.co.uk/cps/rde/xchg/gb/hs.xsl/-/html/more-about-quattron-pro.htm**)

Sharp ducked my questions on this, so I have asked the ASA (Advertising Standards Authority) to investigate their claim.

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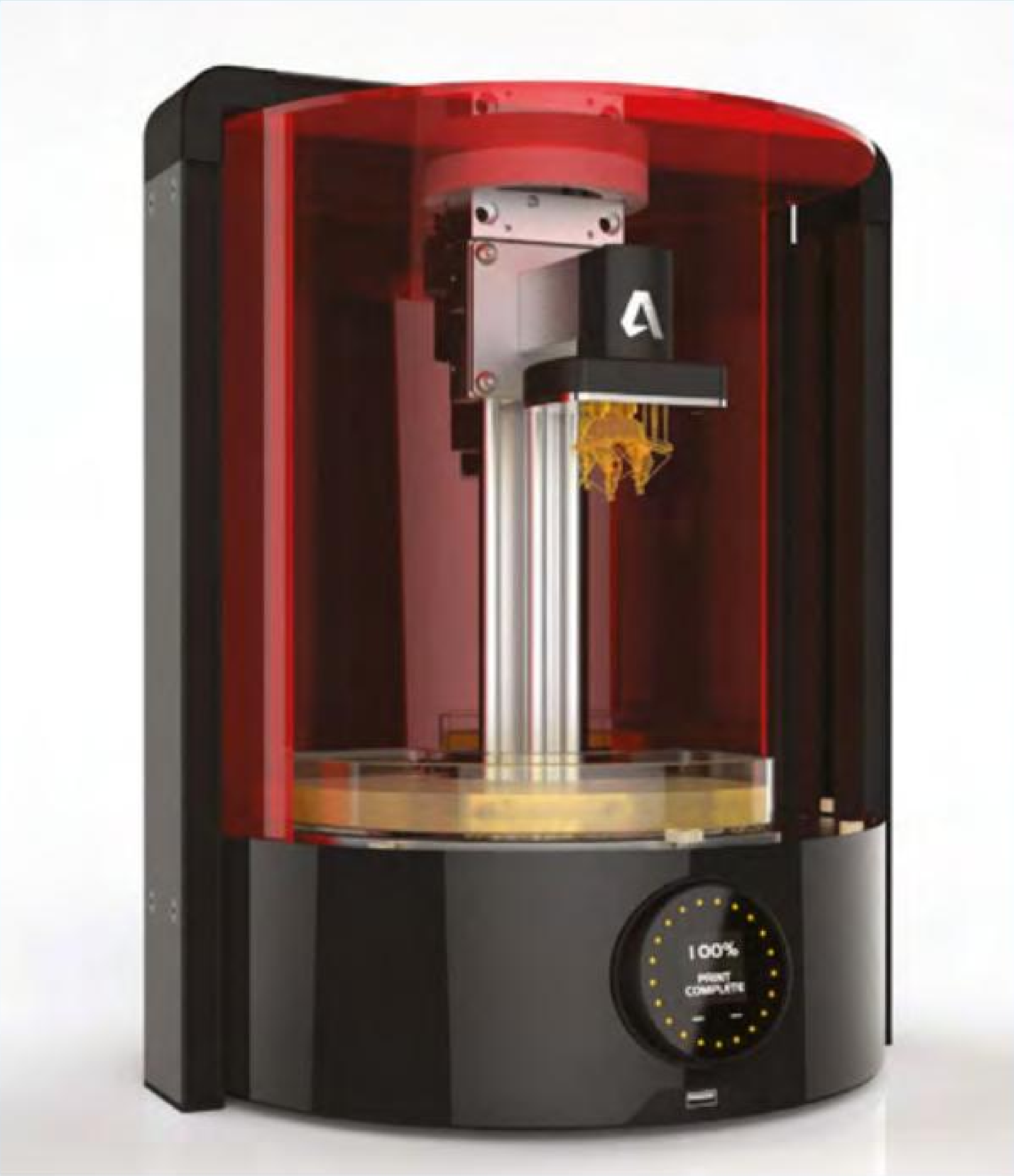
Building the next industrial revolution



Autodesk's 3D printer uses ultraviolet light to harden liquid plastic in a highly controlled way.

Until now, most people associated Autodesk, the makers of Autocad 3D design software, with just virtual design tools, but now the software giant is taking a leap from virtual to real by developing a 3D printer.

The technology Autodesk has adopted is based on the technique of 'stereolithography'. The 3D printer creates objects by hardening a liquid plastic with a laser beam. Ultraviolet light is traced in a finely controlled manner over a cross-section of the intended design. A thin shell of exposed resin is turned solid and the remaining material is removed. Repeating this process can build up any pre-programmed shape.

This is fundamentally different from cheaper printers, which extrude (squeeze out) thin strings of melted plastic from nozzles. The downside is that the stereolithographic process is more expensive, more complicated, but crucially it can deliver smoother, and more detailed objects.

3D printing has the potential to fundamentally change how things are designed and made, but the industry is still in its infancy. Autodesk say that they want to enable the acceleration of innovation in 3D printing, and make it accessible and relevant to millions, if not billions, of people.

Open source

'Spark', the name of Autodesk's printer software will be an open platform that will make it easier for hardware manufacturers, software developers, materials scientists, product designers, and others to participate in and benefit from the technology. It will be open and freely licensable to hardware manufacturers and others who are interested. The design of the printer will also be made publicly available to allow for further development and experimentation. The printer will be able to use a broad range of materials, made by Autodesk and others, opening the way for lots of exploration with new materials.

Device charging without wires

WiTricity, a pioneer in wireless power transfer over distance, has signed a technology licensing agreement with Intel. The two will work together to enable efficient, high performance wireless charging solutions for computing devices, enabling more freedom from mains-powered charging – their ultimate vision is to eliminate all wires from all platforms.

The agreement is centered on the 'Rezence' specification, which has been adopted by some of the world's leading mobile chipmakers, phone manufacturers, and other key industry players. Rezence is a wireless power transfer technology and specification, based on magnetic resonance. Although older, first-generation charging technologies work well enough when a single device is positioned perfectly on a charging pad, they have limited range. They are also unable to handle different power requirements at the same time (charging a tablet and smartphone together), or function in the presence of metal (keys, coins and metal-backed devices). These problems made this technology impractical.

Thanks to the use of magnetic resonance, Rezence is designed to be 'spatially free', extending wireless power applications 'beyond the mat', and avoiding the need for accurate alignment of charging coils. This brings benefits: superior charging range through almost any material; multi-device charging and immunity to the effects of everyday metal objects.

Got an idea?

The Internet, low-cost manufacturing and crowdfunding schemes (eg, Kickstarter) make this a golden age for inventers and entrepreneurs – but how do you protect your ideas? Intellectual property (IP) specialists Marks & Clerk recommend budding tech developers protect marketshare, revenue streams and future finance raising by ensuring they have at least five systems in place to protect their IP:

1. Avoid disclosures – keeping your idea confidential helps ensure it remains a 'new' product or process, an essential factor for obtaining patent approval; ensure you have confidentiality and IP agreements in place with all third parties, before disclosure

2. Keep records – in the event of any potential disputes, records of conversations and correspondence could be useful as evidence

3. Pursue patent protection as early as possible – this will help increase commercial value and longevity, a key consideration for future development or expansion

4. Review your patent application at key milestones – it is imperative to remember that a patent application and a patent are not the same

5. Seek professional advice – a patent application needs to be drafted and prosecuted by a qualified attorney with the appropriate experience.

1000-mile battery

Israeli company Phinergy has teamed up with Canadian metal producer Alcoa to develop battery technology that allows an all-electric car to travel up to 1,100 miles between charges.

The technology is a combination of aluminium-air and lithium-ion batteries, and was demonstrated using an all-electric, sub-compact car at the Circuit Gilles-Villeneuve racetrack in Montreal.

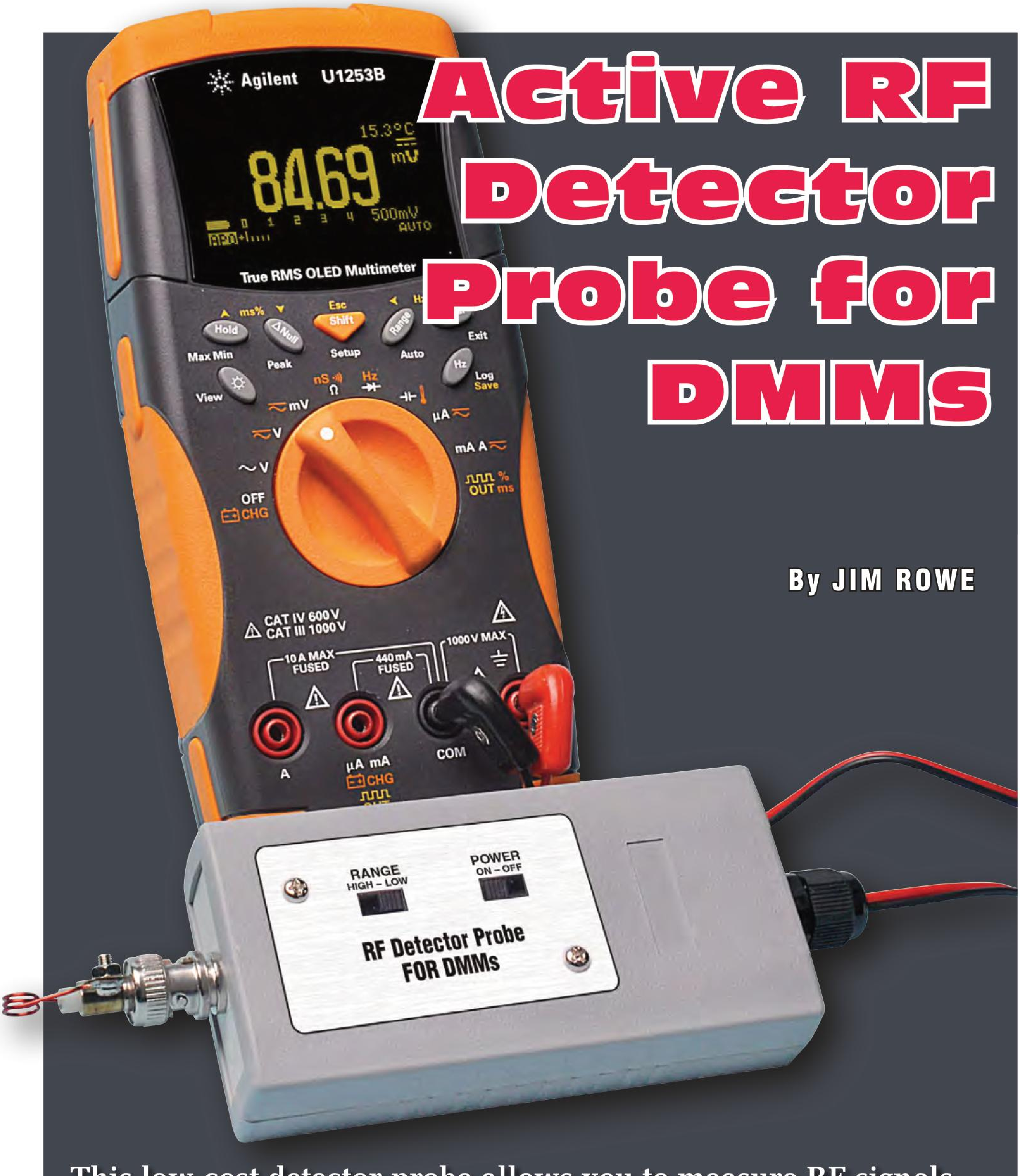
Alcoa and Phinergy are collaborating on new materials, processes and components to commercialise the aluminium-air battery, which creates energy by combining aluminium, ambient air and water.

Elite Pi honour

Fans of the seminal video game 'Elite' and the Raspberry Pi computer will be pleased to hear that David Braben has been awarded an OBE in the Queen's Birthday Honours list. Braben co-wrote Elite and was instrumental in setting up the Raspberry Pi Foundation, a charitable organisation responsible for developing and launching the phenomenally successful Raspberry Pi.

Active RF Detector Probe for DMMs

By JIM ROWE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This low-cost detector probe allows you to measure RF signals from below 100kHz up to over 1GHz with your DMM for signal voltages between about 20mV and 10V RMS. You can use it with a probe or a sniffer loop and you can even use it to measure the voltage across a coaxial cable load and calculate the RF power.

ACTIVE RF DETECTOR PROBE FOR DMMS

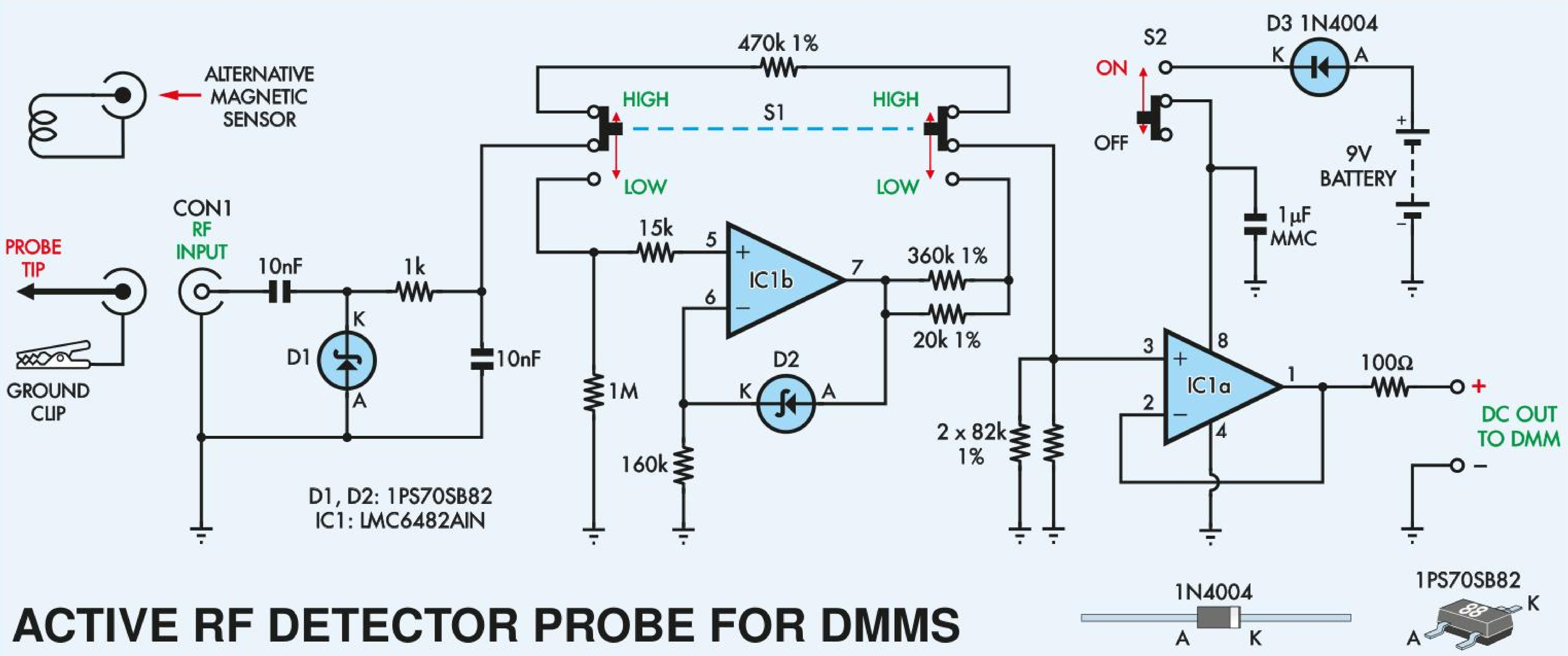


Fig.1: the circuit for the *Active RF Detector Probe*. When S1 selects the high range, the detected RF signal is rectified by D1, attenuated by a voltage divider and fed to voltage follower stage IC1a, which then drives a DMM. Alternatively, on the low range, the detected signal from D1 is fed to IC1a via a linearity compensation circuit based on op amp IC1b.

IT'S NOT DIFFICULT to measure RF signals if you have access to an RF power meter or spectrum analyser – but these are expensive instruments (£1000 plus). You simply can't justify their cost, unless you work a lot with RF and communications equipment. So what can you use to make the occasional RF signal measurement?

The usual approach is to use a passive RF detector probe connected to your DMM. By using a Schottky diode in the detector, these can give acceptable results for signals between about 500mV and 50V RMS, and between say 10MHz and 500MHz or so. But they're usually not much use for measuring signals below 500mV, due to non-linearity of the detector diode's forward conduction characteristic. Signals larger than about 50V also tend to be a problem, because of the diode's maximum reverse voltage rating.

Recently, I needed an RF detector probe that would be capable of measuring quite small signals – much lower than 500mV. I searched on the Internet and found the circuit of an 'active' RF detector probe using a nifty linearity compensation scheme developed originally by US radio amateur John Grebenkemper, KI6WX, for use in SWR bridges. This probe was claimed to be useful for measuring signals between 100kHz and 30MHz.

Experimenting with this circuit, I soon realised that its basic configuration could be refined to produce a version capable of working up to much higher frequencies. The result is the new design described in this article. It is capable of making measurements from below 100kHz to above 1GHz, for signals from about 20mV up to 10V RMS (in two ranges). It's low in cost, easy to build and particularly flexible in terms of the measurements it can make.

Circuit details

Fig.1 shows the complete circuit details for the probe. The actual RF detector diode is D1, a very tiny 1PS70SB82 UHF Schottky diode. It's connected in a standard half-wave configuration and produces a DC voltage across the 10nF filter capacitor that's very close to the peak value of the RF input signal.

When range switch S1 is in the HIGH position, this DC voltage is fed to the pin 3 input of op amp IC1a via a resistive voltage divider formed by a 470kΩ resistor and two paralleled 82kΩ resistors. The divider ratio is set so that the DC voltage fed to pin 3 of IC1a is equal to 0.0707 times the peak value of the input voltage, after allowing for losses in the detector, corresponding to one-tenth of the RMS value of the RF input.

Since IC1a (one half of an LMC6482 dual CMOS op amp) is connected as a voltage follower, this is the voltage fed out to the DMM.

Why do we attenuate the detector output by 0.0707 on this range and not just by 0.707, corresponding to the full RMS voltage of the RF input? It's because IC1 is operating from a supply voltage of about 8.4V (9V minus the 0.6V drop in D3), and so it can't handle signal levels greater than this. By dividing down by 10 as well, we allow the probe to measure signals up to the PIV (peak inverse voltage) rating of D1. This is 15V, corresponding to an RF input of 10.6V RMS.

So when the probe is switched to the HIGH range, the output of the detector diode is fed without any linearity compensation to IC1a, via the voltage divider. IC1a feeds this uncompensated DC voltage out to the DMM, merely lowering the source impedance so that accurate readings should be produced regardless of the DMM's input resistance. In any case most DMMs have an input resistance of 10MΩ or more on the DC voltage ranges.

On the HIGH range, the probe can measure RF signals between about 600mV and 10V RMS. The only complication on this range is that there's a built-in 10:1 division, so the DMM reads one-tenth the RMS value of the RF input signals, ie, 1.00V RMS becomes 100mV DC and so on.

Low range

Things get a little more interesting when you move range switch S1 to the LOW position. As you can see, this switches the 470kΩ divider resistor out of circuit and instead switches

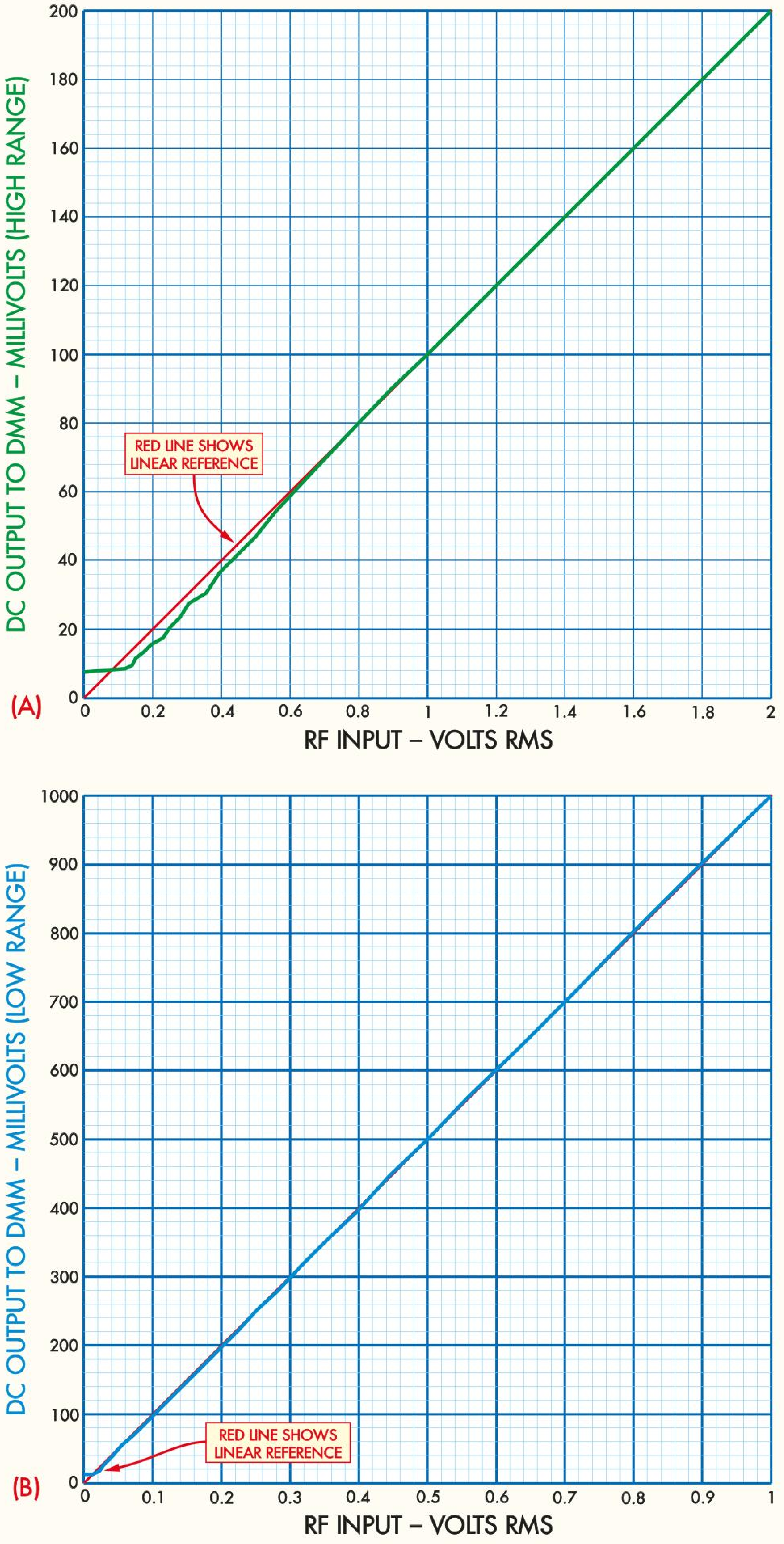


Fig.2: the top graph (A) shows how the linearity response (green) on the HIGH range deviates from the linear reference line (red) for signal levels below 600mV. By contrast, the bottom graph (B) shows that the linearity response on the LOW range only deviates from the red reference line for levels below 20mV due to the response of the linearity compensation circuit.

in a 'linearity compensation' circuit based on IC1b and diode D2, another 1PS70SB82 Schottky diode.

IC1b is connected as a non-inverting amplifier stage, with D2 forming part of the negative feedback circuit – along with a 160kΩ resistor connected from pin 6 to ground. The combination of D2 and the 160kΩ resistor forms a non-linear voltage divider. This divider varies IC1b's gain according to the DC voltage level at its pin 7 output, in a manner that closely compensates for the non-linearity in detector diode D1.

As a result, the DC voltage at pin 7 is closely proportional to the peak level of the probe's RF input voltage, at levels right down to 20mV.

The paralleled 360kΩ and 20kΩ resistors connected from pin 7 of IC1b to the LOW side contact of switch S1 form the upper leg of an output voltage divider for this range, with the lower leg formed by the two paralleled 82kΩ resistors from pin 3 of IC1a to ground. The division ratio of this divider is arranged to make the DC voltage appearing at pin 3 of IC1a directly proportional to the RMS value of the RF input voltage, so that for this range the DMM reads the amplitude of the RF input signals directly.

Power for IC1 comes from a standard 9V alkaline battery, with diode D3 connected in series for reverse polarity protection. As the current drawn by IC1 is typically less than 2mA, the battery should last for almost its shelf life with intermittent use. And that's all there is to the circuit operation.

Linearity performance

The performance you can expect from the Active RF Detector Probe can be seen in the linearity plots of Fig.2 and the frequency response plot of Fig.3. The upper plot (A) in Fig.2 shows the linearity at the lower end of the HIGH range and as you can see, it moves away from the linear reference line (red) at levels below 600mV.

By contrast, the lower plot (B) in Fig.2 shows the linearity at the low end of the LOW range. Here you can see that the DC output only deviates from the red linear reference line at RF levels below 20mV.

Fig.3 shows the measured frequency response of our prototype RF Detector Probe. It's quite flat, at about ±5% up to about 200MHz, then rises up to a peak at 500MHz and to an even larger peak at 750MHz. These peaks are

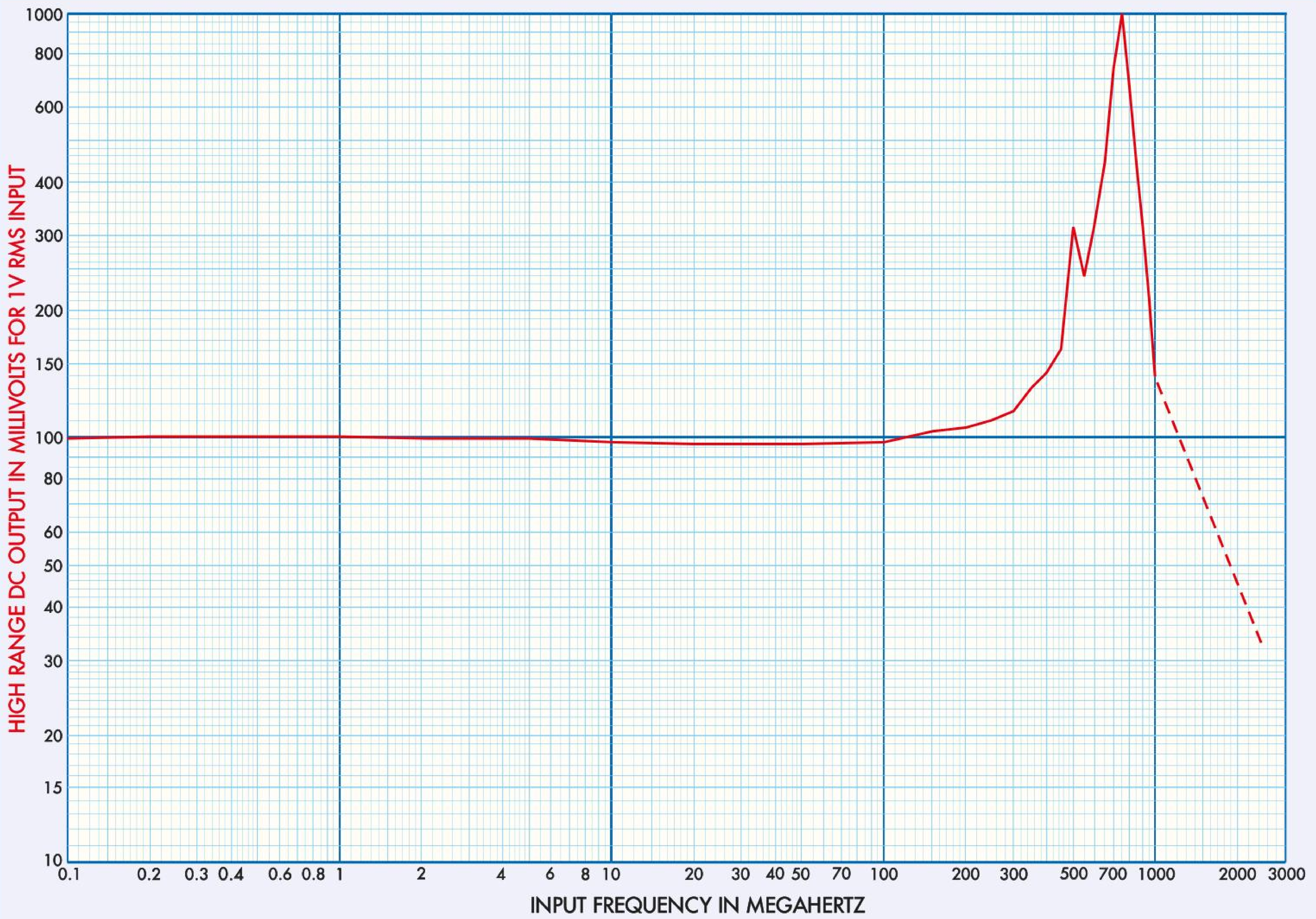


Fig.3: the frequency response of the prototype *Active RF Detector Probe*. It's quite flat up to about 200MHz but then rises steeply to peaks at 500MHz and 750MHz. Use this graph and the plots in Fig.2 to correct the measured RF voltage reading if necessary.

presumably due to resonances in the probe's input circuit (involving D1, the 10nF input coupling capacitor and input connector CON1) and would probably be very hard to remove.

D1, the 10nF capacitors and the 1kΩ resistor are all SMD components and D1 and the 10nF input capacitor are positioned on the PCB as close as possible to CON1. This also helps to ensure good linearity up to 200MHz.

By the way, although the peaks at 500MHz and 750MHz look quite dramatic, they don't mean that the *Active RF Detector Probe* can only be used to make measurements below 200MHz. On the contrary, Fig.3 can be used as a correction curve when making measurements up to 1GHz (1000MHz).

One last point about Fig.3. You might wonder about the significance of the dashed red line extending the plot from 1GHz to 2.45GHz. It's simply my 'best guess' of the probe's response above 1GHz, based on some measurements I was able to make at 2.414GHz, 2.432GHz and 2.450GHz using a small

Parts List

1 ABS instrument case, 120 × 60 × 30mm
1 double-sided PCB, available from the *EPE PCB Service,* code 04107131, 61 × 29mm
2 PCB-mount subminiature DPDT slide switches
2 M3 × 20mm machine screws
2 M3 × 6mm machine screws
2 M3 × 9mm untapped spacers
2 M3 × 10mm untapped nylon spacers (5mm OD)
4 M3 hex nuts
2 M3 flat washers
2 M3 lockwashers
2 40 x 8mm strips of 0.25mm sheet brass
1 panel-mount BNC socket (CON1)
2 crimp-type BNC line plugs, RG6 cable type
1 plastic cable gland (3-6mm cable size)
2 banana plugs, 1 red, 1 black
1 9V battery snap
1 9V alkaline battery
1 black alligator clip lead
1 1.5m length of light-duty 2-core red/black cable
1 30mm length of 1mm-diameter hard brass wire
1 100mm length of 1mm-diameter enamelled copper wire
1 35mm length 6mm-dia heatshrink tubing

Semiconductors
1 LMC6482AIN dual CMOS op amp (IC1)
2 1PS70SB82 UHF Schottky diodes (D1,D2)
1 1N4004 silicon diode (D3)

Capacitors
2 10nF 1206 SMD ceramic
1 1μF MMC ceramic

Resistors (0.25W, 1%)
1 1MΩ
1 470kΩ
1 360kΩ
1 160kΩ
1 100Ω
2 82kΩ
1 20kΩ
1 15kΩ
1 1kΩ 0805 SMD

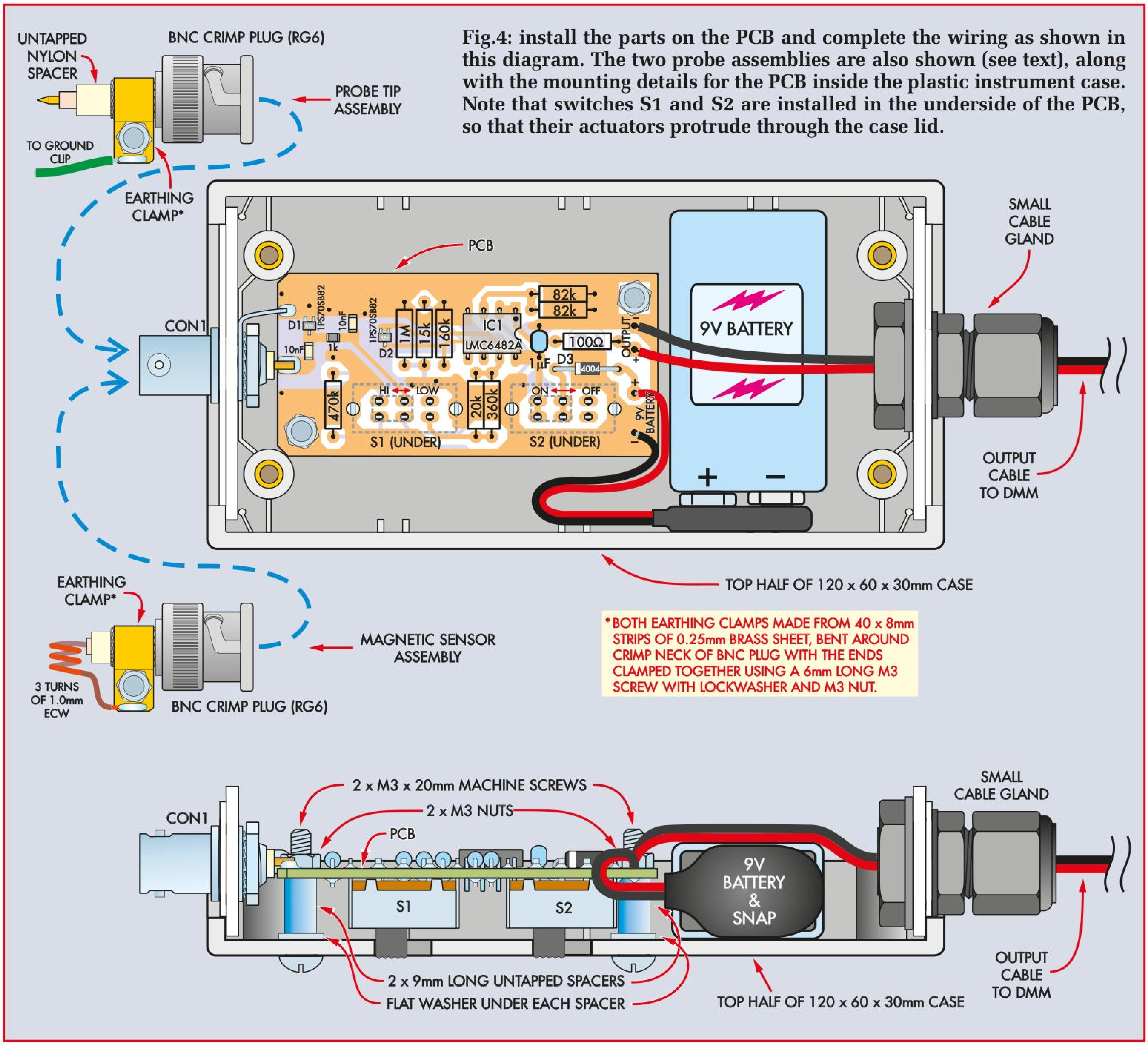


Fig.4: install the parts on the PCB and complete the wiring as shown in this diagram. The two probe assemblies are also shown (see text), along with the mounting details for the PCB inside the plastic instrument case. Note that switches S1 and S2 are installed in the underside of the PCB, so that their actuators protrude through the case lid.

UNTAPPED NYLON SPACER
BNC CRIMP PLUG (RG6)
PROBE TIP ASSEMBLY
TO GROUND CLIP
EARTHING CLAMP*
PCB
CON1
D1
D2
1PS70SB82
10nF
1k
1M
15k
160k
IC1
LMC6482A
82k
82k
100Ω
1µF
D3
4004
OUTPUT
470k
HI
LOW
S1 (UNDER)
20k
360k
ON
OFF
S2 (UNDER)
9V BATTERY
+
–
SMALL CABLE GLAND
OUTPUT CABLE TO DMM
TOP HALF OF 120 x 60 x 30mm CASE
EARTHING CLAMP*
MAGNETIC SENSOR ASSEMBLY
3 TURNS OF 1.0mm ECW
BNC CRIMP PLUG (RG6)
*BOTH EARTHING CLAMPS MADE FROM 40 x 8mm STRIPS OF 0.25mm BRASS SHEET, BENT AROUND CRIMP NECK OF BNC PLUG WITH THE ENDS CLAMPED TOGETHER USING A 6mm LONG M3 SCREW WITH LOCKWASHER AND M3 NUT.
2 x M3 x 20mm MACHINE SCREWS
2 x M3 NUTS
CON1
PCB
S1
S2
9V BATTERY & SNAP
SMALL CABLE GLAND
2 x 9mm LONG UNTAPPED SPACERS
FLAT WASHER UNDER EACH SPACER
TOP HALF OF 120 x 60 x 30mm CASE
OUTPUT CABLE TO DMM

UHF generator module. My main RF signal generator only functions up to 1000MHz, so I couldn't make any measurements between 1.00GHz and 2.414GHz. That's why the response line is dashed over this section.

Construction

Almost all the parts are mounted on a small double-sided PCB, available from the *EPE PCB Service*, coded 04107131 and measuring 61 × 29mm. This assembly is housed in a compact ABS instrument case measuring 120 × 60 × 30mm.

The only parts not mounted on the PCB are RF input connector CON1 (which is fitted to an end panel), the cable gland used to anchor the DC output cable (mounted on the other end panel) and the 9V battery which is mounted inside the case behind the PCB.

Virtually all the parts on the PCB are mounted on the top, the exceptions being slide switches S1 and S2. These are mounted on the underside of the board, so that their actuators can later protrude through matching slots in the case lid (see photo).

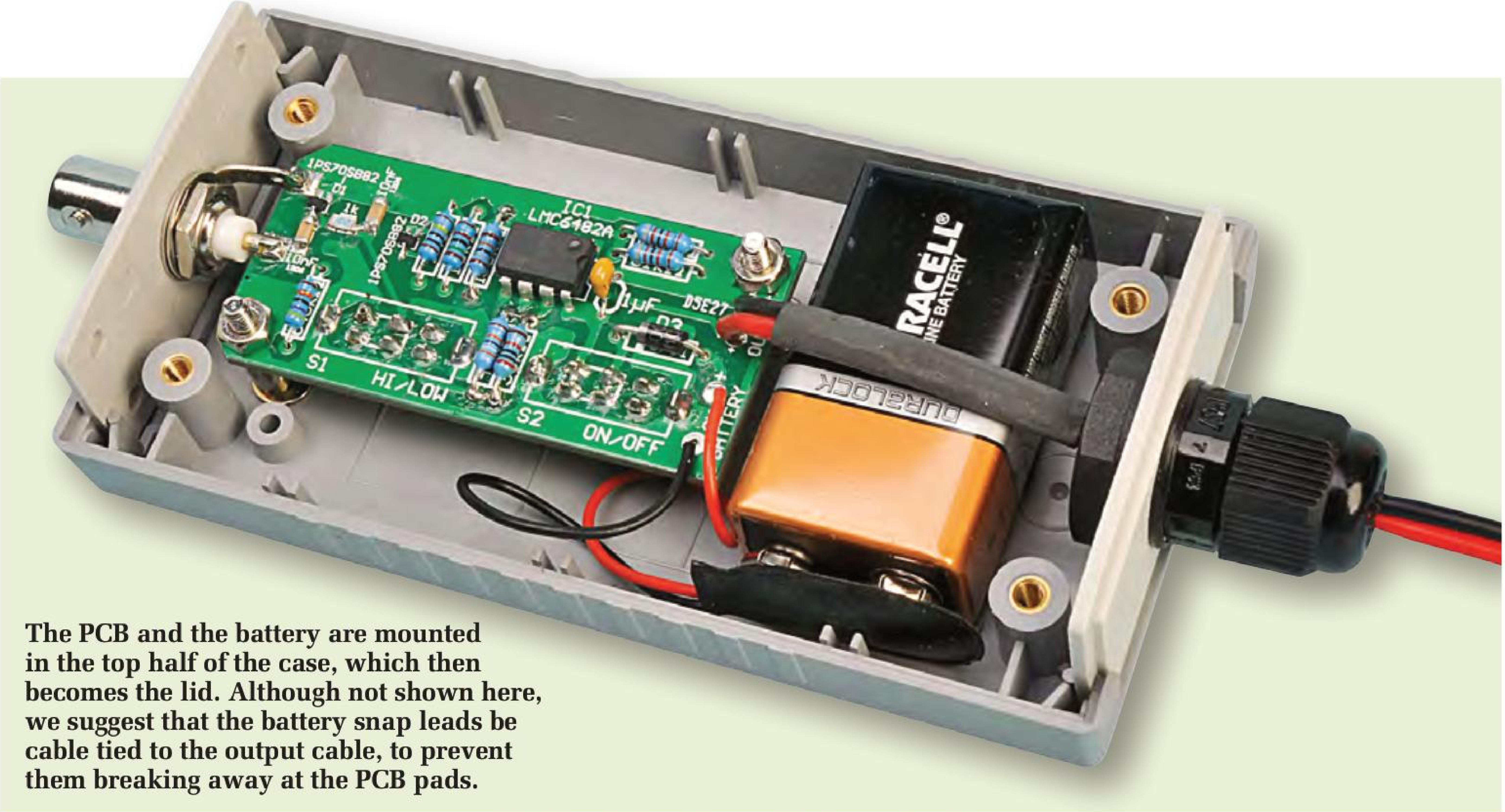
Follow Fig.4 to install the parts on the PCB. It's a good idea to fit the five SMD parts first. These parts are all mounted in the upper lefthand area of the PCB, very close to the connections for input socket CON1. The only polarised SMD parts are D1 and D2, which should both be fitted with their 'two-lead' sides towards the top of the PCB.

Once the SMDs have been installed, the remaining parts can be added. These include the through-hole resistors, the 1µF MMC capacitor, diode D3, IC1 and finally the two slide switches on the underside. That done, solder the battery snap lead in place.

The next step is to solder a 1.5m length of light-duty red/black figure-8 cable to the PCB output terminals. Make sure that the red wire goes to the OUTPUT+ PCB pad and the black lead to the OUTPUT– pad. Once that's done, the PCB assembly is complete and ready for mounting in the case.

Preparing the case

The next step is to drill and cut the various holes required in the top half



The PCB and the battery are mounted in the top half of the case, which then becomes the lid. Although not shown here, we suggest that the battery snap leads be cable tied to the output cable, to prevent them breaking away at the PCB pads.

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	1MΩ	brown black green brown	brown black black yellow brown
☐	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
☐	1	360kΩ	orange blue yellow brown	orange blue black orange brown
☐	1	160kΩ	brown blue yellow brown	brown blue black orange brown
☐	2	82kΩ	grey red orange brown	grey red black red brown
☐	1	20kΩ	red black orange brown	red black black red brown
☐	1	15kΩ	brown green orange brown	brown green black red brown
☐	1	100Ω	brown black brown brown	brown black black black brown

of the case and the two end panels. The locations and sizes for all of these holes are shown in Fig.5. The four circular holes can be drilled and/or reamed to size and in each case, it's best to start with a small pilot drill.

The two rectangular holes are for S1 and S2. They can be made by first drilling a series of small holes around the inside perimeter, then knocking out the centre piece and carefully filing them to shape using jeweller's needle files.

Once all the holes have been made, download the front-panel artwork (in PDF format) from the *EPE* website, print it out and laminate it. Alternatively, if you don't have access to a hot laminator, print it out onto photo paper. That done, cut out the switch holes and the two screw holes using a hobby knife, trim the label to size and attach it to the upper half of the case using double-sided tape.

The PCB assembly can now be mounted inside the upper half of the case. Fig.4 shows the mounting details. As can be seen, it's supported on two M3 × 9mm untapped spacers plus a flat washer under each spacer, and secured using M3 × 20mm machine screws and M3 nuts.

The flat washer under each spacer is necessary to ensure that the PCB is spaced up from the case by nearly 10mm. This allows the slide switches to just protrude through their matching rectangular holes and, at the same time, ensures that the top of the PCB subsequently sits just under the centre contact spigot of CON1.

CON1 can now be mounted on the lefthand end panel. Make sure that its earthing lug is oriented horizontally in the direction shown on Fig.4 and that the attachment nut is firmly tightened. This panel is then lowered into the lefthand end of the case and CON1's earth lug bent around as shown so that it sits just above the matching earth solder pad on the PCB.

The earth lug and CON1's centre spigot can now be soldered to their respective pads.

Final assembly

Now for the final assembly. First, slip a 35mm-long length of 6mm-diameter heatshrink over the output cable and slide it right down to the PCB (it later runs across the battery). That done, fit the cable gland to the righthand end-panel, then pass the output cable through it and lower this end assembly into place.

The next step is to fit the battery, after which most of the slack can be taken out of the output cable and the cable gland tightened. The battery will now be secured under the output cable, with the heatshrink running across it.

The free-end of the output cable must be fitted with banana plugs, to make the connection to the DMM. Fit a red plug to the red (+) output lead and a black plug to the black (–) lead.

The *Active RF Detector Probe assembly* is now complete and you can fit the lower half of the case, fastening it all together using the four countersink-head M3 screws supplied with it.

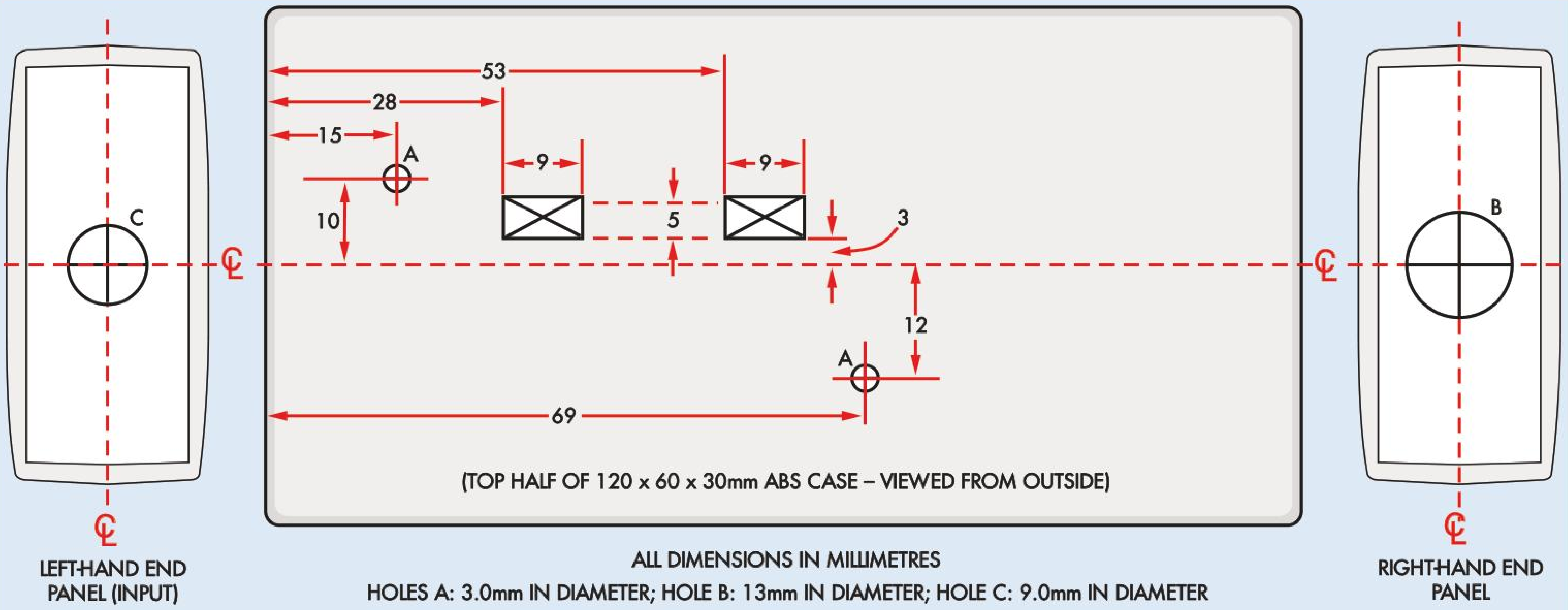

53
28
15
A
9
9
10
5
3
C
B
12
A
69
℄
(TOP HALF OF 120 x 60 x 30mm ABS CASE – VIEWED FROM OUTSIDE)
LEFT-HAND END PANEL (INPUT)
ALL DIMENSIONS IN MILLIMETRES
HOLES A: 3.0mm IN DIAMETER; HOLE B: 13mm IN DIAMETER; HOLE C: 9.0mm IN DIAMETER
RIGHT-HAND END PANEL

Fig.5: this diagram can either be copied or downloaded from the *EPE* website and used as a template for drilling the two end panels and the top half of the case. The switch cutouts can be made by drilling a series of small holes around the inside perimeter, then knocking out the centre piece and filing to shape.

Making the probe tips

Before using the unit, you first have to make the two interchangeable probe tips – or to be more accurate, a probe tip and a magnetic sensor (or sniffer) probe.

As shown in Fig.4, these are both based on a standard crimp-type BNC line plug (ie, where the centre conductor of a coaxial cable is soldered to the plug's centre pin, but the outer shielding braid is connected to a ferrule on the rear of the plug by crimping it inside a thin metal sleeve).

In this case, we're using plugs designed for crimping onto RG6 cable, as these have a ferrule with an inner diameter of about 5mm.

Here though, we don't actually crimp the earth connections to the BNC plug ferrules. Instead, the earth connections are soldered to small P-clamps which are then attached to the ferrules using M3 × 6mm machine screws, lockwashers and nuts (see photo).

The P-clamps are bent from 40 × 8mm strips of 0.25mm brass sheet, with 3mm holes drilled in the flat ends to accept the M3 screws. Once made, secure them to the BNC plug ferrules as shown.

Probe tip assembly

The probe tip assembly is made using a 30mm length of 1mm-diameter hard brass wire, with a sharp point ground or filed at one end. The other end of this wire is then passed into the rear of the plug's centre pin and secured by soldering the two together (don't leave a large solder 'blob' at the joint though). That done, the pin-and-tip assembly is pushed all the way into the plug (from the ferrule end) until the pin 'clicks' into position inside the connector.

Once the tip assembly is in place, you then slip an M3 × 10mm untapped nylon spacer (outer diameter 5mm) into the rear of the ferrule, to act as an insulator/dielectric. A short length of PVC insulation from a 230V mains lead conductor is then slipped inside the nylon spacer to support the probe tip more securely. Finally, a short earth lead (eg, about 70mm long) fitted with an alligator clip is soldered to the brass P-clamp.

Magnetic sensor probe

The magnetic sensor (sniffer) probe is made in a similar way. However, instead of using a 30mm-length of brass wire for the tip, we instead use a 100mm-length of 1mm-diameter enamelled copper wire, with its centre section first bent around a 3.5mm rod or mandrel (eg, a 3.5mm drill bit) to form three neat turns.

Both ends of the wire are then scraped for about 4mm, after which one end is soldered into the rear of the plug's centre pin. A nylon spacer

Specifications

- An RF Detector Probe designed to allow low-level RF signals to be measured using a standard DMM (set to volts DC). It provides two measurement ranges, with the LOW range incorporating compensation for detector diode non-linearity. The input configuration allows use of a probe tip for electrical coupling, a magnetic sensor for magnetic coupling or a direct coaxial connection for RF power measurements (see text).
- **Input impedance:** approximately 1kΩ.
- **Output resistance:** <1kΩ.
- **Frequency response:** from below 100kHz to 200MHz ±5%, rising to peaks at 500MHz and 750MHz; see Fig.3. This plot can be used to correct readings for measurements above 200MHz.
- **High range linear coverage:** RF signals from 600mV to 10V RMS. Maximum input level 10.6V RMS.
- **Low range linear coverage:** RF signals from 20mV to about 5V RMS. Maximum input level 5.6V RMS (note: maximum DC input level for both High and Low ranges is 50V).
- **Power supply:** internal 9V alkaline battery; battery drain < 2mA.

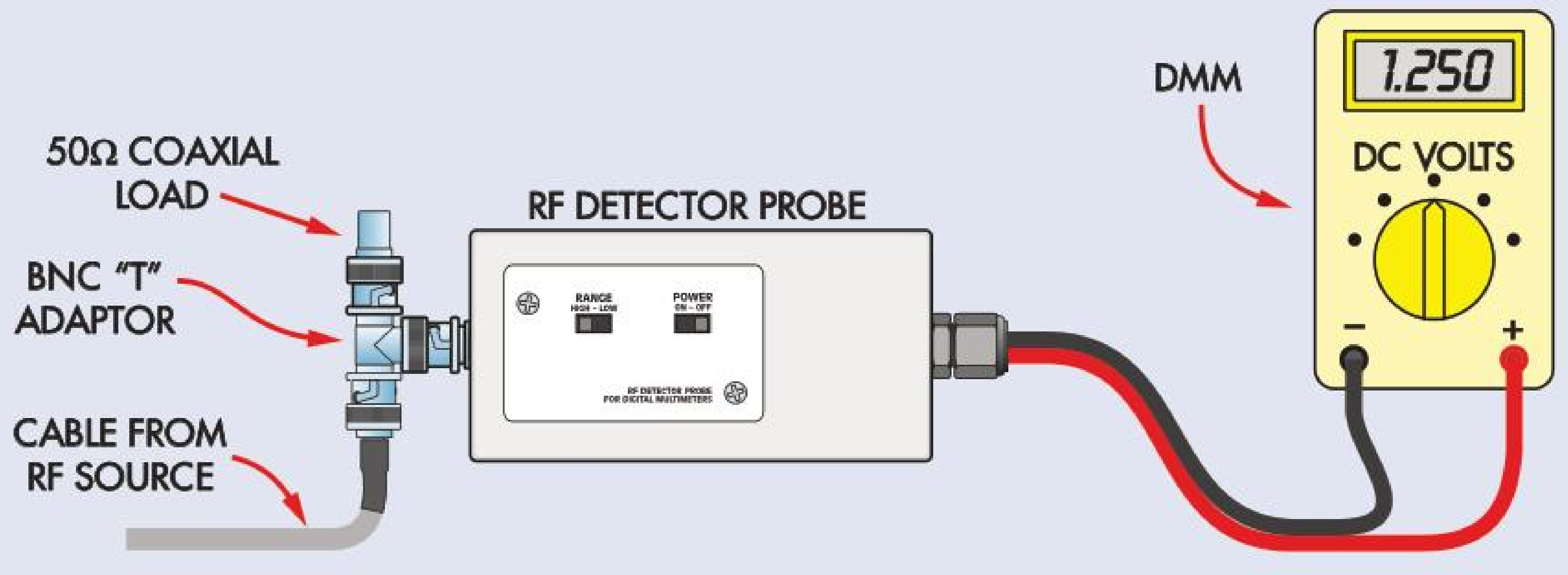


Fig.6: direct RF voltage measurements can be made in coaxial cables by using the configuration shown here. Because the load resistance is known (ie, 50Ω), this also allows you to calculate the RF power (see also Table 2).

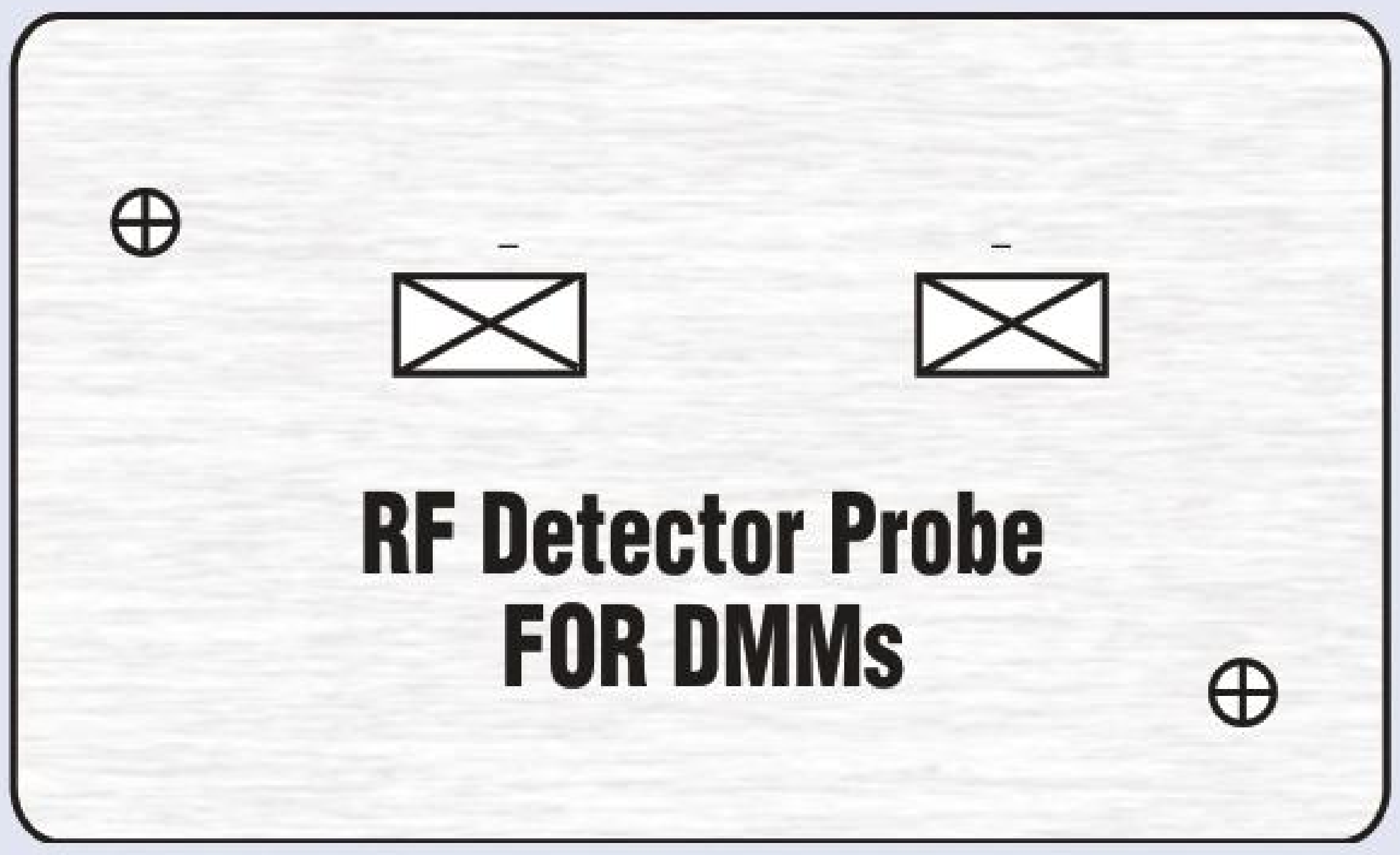


Fig.7: this front-panel artwork can be copied and laminated. The artwork can also be downloaded in PDF format from the *EPE* website.

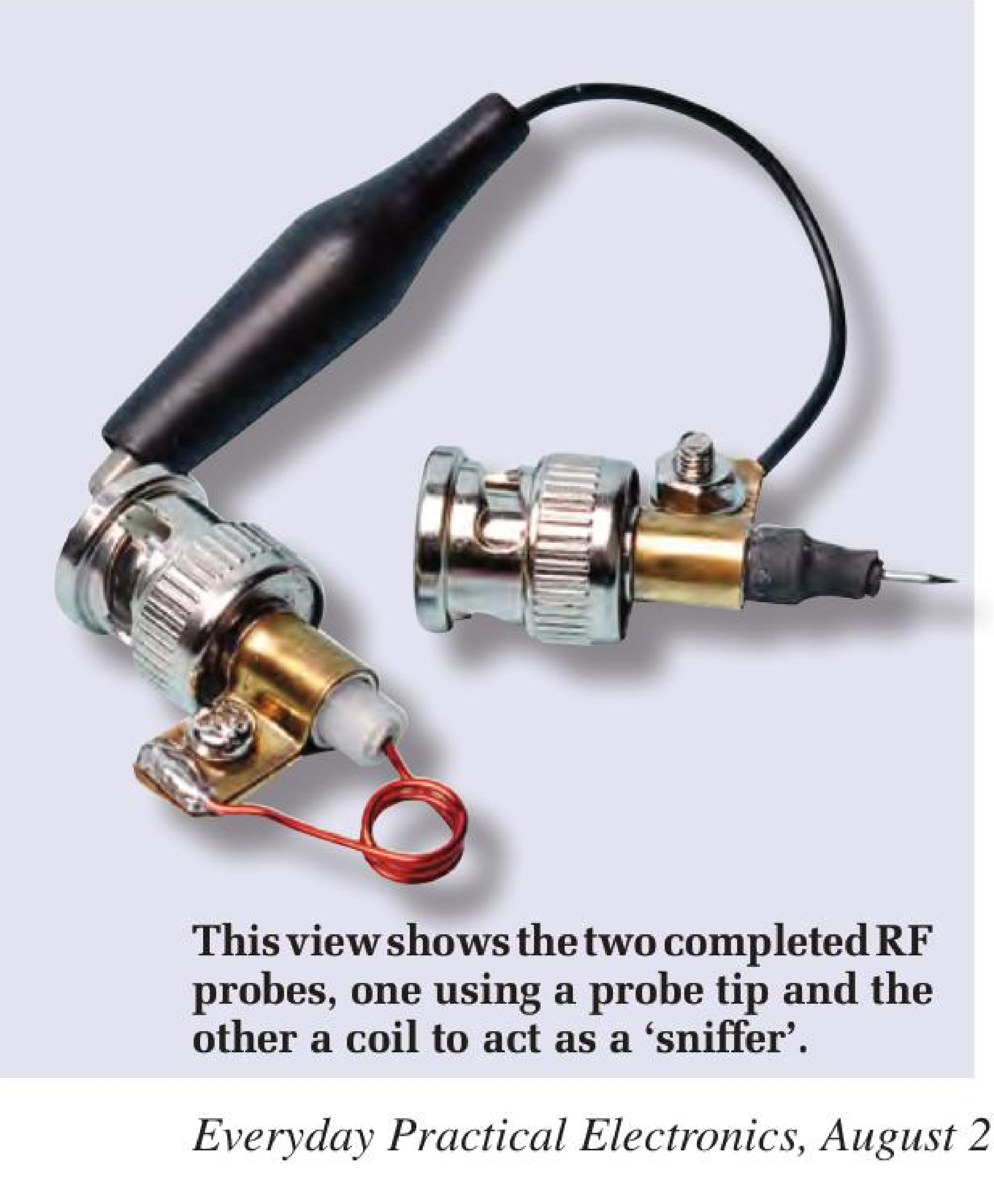
Table 2: Volts to Power Conversion

VOLTS RMS	POWER (50Ω)	VOLTS RMS	POWER (50Ω)
10.0	2.0 W	446 mV	4.0 mW
8.9	1.6 W	398 mV	3.2 mW
7.9	1.26 W	354 mV	2.5 mW
7.07	1.0 W	316 mV	2.0 mW
6.30	794 mW	282 mV	1.6 mW
5.62	631 mW	251 mV	1.26 mW
5.01	501 mW	224 mV	1.00 mW
4.46	398 mW	199 mV	790 µW
3.98	316 mW	178 mV	630 µW
3.54	251 mW	158 mV	500 µW
3.16	200 mW	141 mV	400 µW
2.82	158 mW	126 mV	320 µW
2.51	126 mW	112 mV	250 µW
2.24	100 mW	100 mV	200 µW
1.99	79 mW	89 mV	160 µW
1.78	63 mW	79 mV	126 µW
1.58	50 mW	71 mV	100 µW
1.41	40 mW	63 mV	80 µW
1.26	32 mW	56 mV	63 µW
1.12	25 mW	50 mV	50 µW
1.00	20 mW	44.6 mV	40 µW
890 mV	19 mW	39.8 mV	32 µW
790 mV	12.6 mW	35.4 mV	25 µW
710 mV	10 mW	31.6 mV	20 µW
630 mV	8.0 mW	28.2 mV	16 µW
560 mV	6.3 mW	25.1 mV	13 µW
501 mV	5.0 mW	22.4 mV	10 µW

and an inner PVC sleeve are then fitted inside the plug's ferrule, after which the pin end of the coil wire is pushed carefully into place until the pin clicks into position inside the BNC connector.

It's then just a matter of carefully bending the sniffer coil's free end into position so that it can be soldered to the previously-installed P-clamp.

Using the RF probe



This view shows the two completed RF probes, one using a probe tip and the other a coil to act as a 'sniffer'.

There are no adjustments to make before using the probe. It's simply a matter of plugging the output cable into the input jacks of your DMM, setting the DMM to an appropriate DC voltage range (eg, 20.0V, 2.00V or 200mV) and then setting the two switches on the probe.

S2 simply switches the power, while S1's position mainly depends on the likely signal level that's to be measured. If you're not sure of this, it would be a good idea to push S1 into the HIGH position, just to be safe. You can then select the LOW position for a more accurate reading if the signal proves to be lower than about 1V RMS.

Note that if you want to measure RF signal voltages, you'll mainly want to use the probe tip and its ground lead. That's because the magnetic sensor provides an induced voltage due to RF current in the circuit you're testing. So the voltage readings don't mean much, although they do allow you to make comparisons.

Because we have used a BNC coaxial socket as the input for the *Active RF Detector Probe*, this also allows it to be used for direct RF voltage measurements in coaxial cables. This means that it can be used in conjunction with a 50Ω coaxial load and a look-up table to make low-power RF power measurements, by using the configuration shown in Fig.6.

As you can see, this involves fitting a BNC T-adaptor to the probe's input socket and then fitting a 50Ω coaxial load to one side. The input cable from the low-power RF source you want to measure is then connected to the other socket of the T-adaptor, and Bob's your uncle.

Of course, the *Active RF Detector Probe* and DMM combination only measures RF voltage; it doesn't measure power directly. However, it's relatively easy to convert the voltage level into power, since you also know the load resistance.

For example, if you're using a 50Ω load as shown in Fig.6, you can use Table 2 to look up the value. Just don't forget to correct the voltage reading using the plots in Figs.2 and 3 – and also multiply the reading by 10, if you're using the Probe's HIGH range – before you convert it to power.

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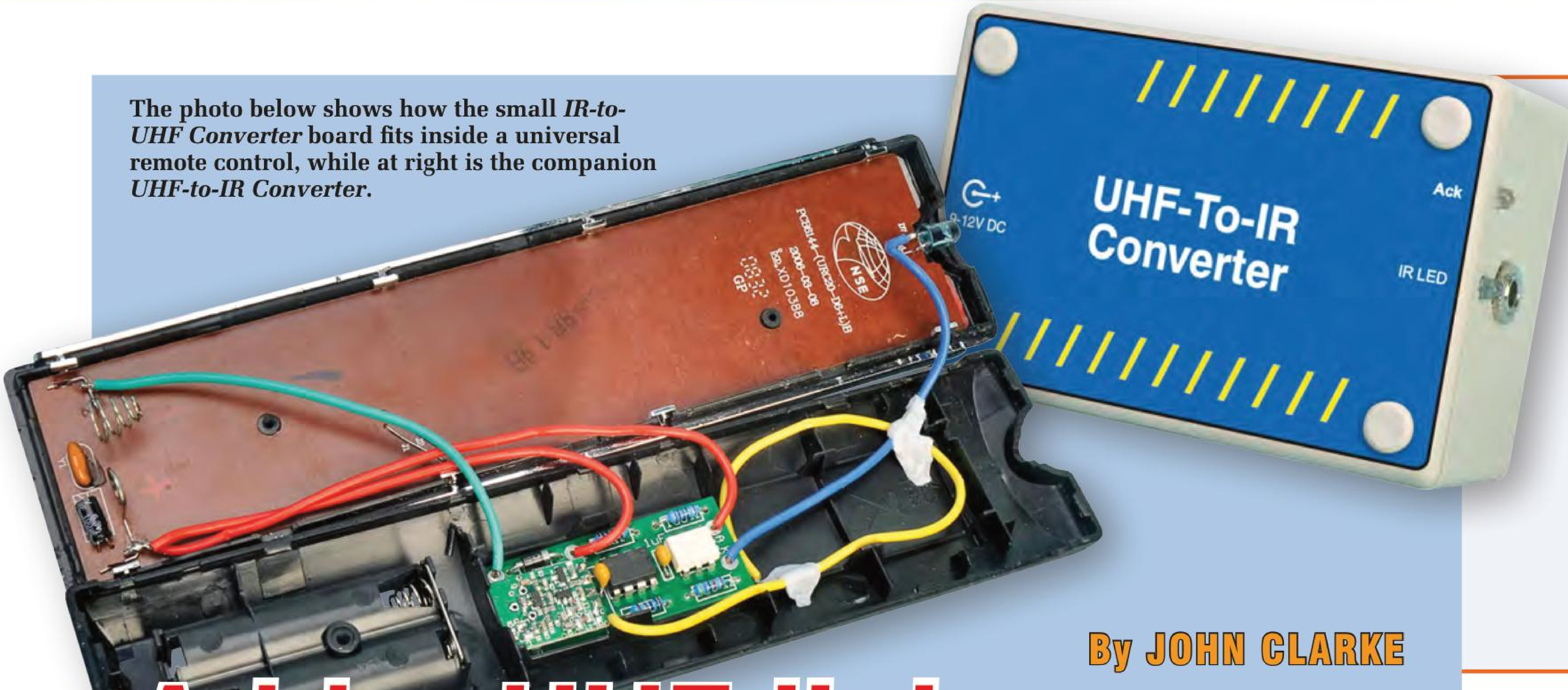
The photo below shows how the small *IR-to-UHF Converter* board fits inside a universal remote control, while at right is the companion *UHF-to-IR Converter*.



By JOHN CLARKE

Add a UHF link to a universal remote control

Remote control extenders are old hat! Now you can add this tiny UHF module to your IR remote control and operate appliances from anywhere inside or outside your home. As well as the tiny module inside the remote, you also need our *UHF-to-Infrared Converter,* which is positioned close to the device to be controlled.

OVER THE YEARS, we have produced several remote control projects using UHF or infrared.

Both approaches make sense, but why not have a remote control that works at both infrared and UHF, rather than having a separate transmitter unit? So that is what this project is about. You build a tiny UHF module into the remote control and power it from the remote's AA cells; there's no external remote transmitter and power supply to worry about.

Of course, you still need a UHF receiver/IR converter at the appliance end, and that's also described here.

This approach is so much more convenient than past remote control extenders. For example, say you are out on the balcony having a pleasant lunch and the CD player is inside providing background music. Want to change a track and change the volume? No need to wander back inside, find the remote and then wander out again. You just pick up the same hand-held remote that you use inside and use it where you are.

Both the UHF and infrared signals are radiated simultaneously, so it does not matter whether you are inside your home or outdoors.

Sound like a good idea? We thought so too, and this project is the result.

We have designed a small PCB module that fits inside the remote control case. You will need to check that it will fit inside the remote control that you want to convert. Some remote controls will be too small or have very little room inside the case, but many do have enough room, particularly universal remotes.

What about current drain?

But what about the extra current that will be drawn by the UHF module? Will it drain the cells by too much and greatly reduce their life? No-one likes having to continually replace batteries in remote controls.

For this reason, we have been very careful with this aspect and the current drain is truly negligible. Typically, it will be just a few nanoamps, although we measured one of our prototypes at just 200 picoamps! That's much less than one thousandth of a microamp!

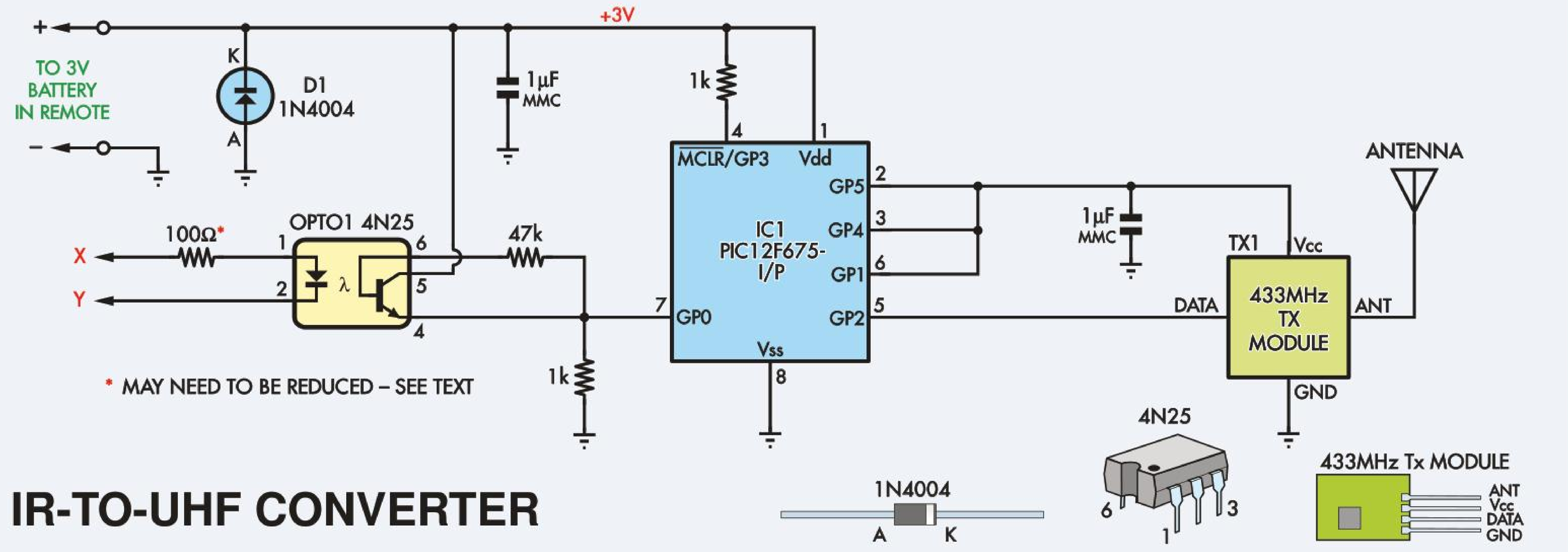


Fig.1: the *IR-to-UHF Converter* circuit. The IR LED driver circuit in the remote feeds the 38kHz signal in via OPTO1 and this drives pin 7 of PIC microcontroller IC1. The micro then powers and drives the 433MHz transmitter module (TX1).

Compare that with the typical microamp or so drawn by a remote control from its AA or AAA cells. Naturally, more current is drawn from the battery when transmitting both the IR and UHF pulsed signal, but it still does not amount to much. In a typical universal remote, the average current while transmitting increases from 10mA with IR transmission alone to 12mA with both IR and UHF transmission – an increase of just 2mA.

Since remote controls only draw significant current while buttons are being pressed, the overall extra current drain with UHF transmission added is unimportant. The AA or AAA cells will still last their shelf life (years).

The companion *UHF-to-IR Converter* is housed in a small plastic case. At one end of the case it has a red acknowledge LED as well as an IR LED to retransmit the received UHF signal as an IR signal. As well, there is a 3.5mm socket to allow connection of an external IR LED (ie, via a cable).

The converter runs from a 9-12V DC plugpack and it draws a maximum of 50mA when transmitting, so any 9-12V DC plugpack will be suitable.

Circuit details

Fig.1 shows the circuit of the *IR-to-UHF Converter* to be built into the remote control. It uses an optocoupler (OPTO1), a PIC12F675 microcontroller (IC1) and a tiny UHF transmitter module (TX1) which runs at 433MHz. As stated, it's powered from the remote's two AA (or AAA) cells (ie, 3V).

The optocoupler is needed to allow for any of the possible LED drive arrangements and provides isolation from the rest of the circuit. The various possibilities are shown in Fig.2. The input of the optocoupler connects, via a 100Ω resistor, across the IR LED drive circuit on the remote control's PCB.

For example, in a typical universal remote, the IR LED drive is as depicted in Fig.2(a). In this case, the 'X' terminal input to the optocoupler connects to the +3V supply rail and the 'Y' terminal connects to the cathode of the IR LED.

For arrangements such as Fig.2(b), the +3V positive rail is easily accessible, but the LED driver output needs to be picked off the series resistor itself. You may need to lift out the remote's PCB to access this resistor.

The optocoupler's internal transistor is connected as an emitter follower, with its base tied to the emitter with a 47kΩ resistor to speed up switching. The resistor effectively discharges the transistor's base each time the opto's internal IR diode stops emitting (ie, at the end of each pulse in the 38kHz signal burst). This allows the transistor to switch off faster than if its base were left floating.

The opto's emitter signal is applied to the GP0 input (pin 7) of microcontroller IC1. With no 38kHz signal burst present at pin 7, IC2 is in sleep mode. Its GP1, GP2, GP4 and GP5 outputs are all low, so transmitter TX1 is off and the circuit draws minimal power at around 12nA.

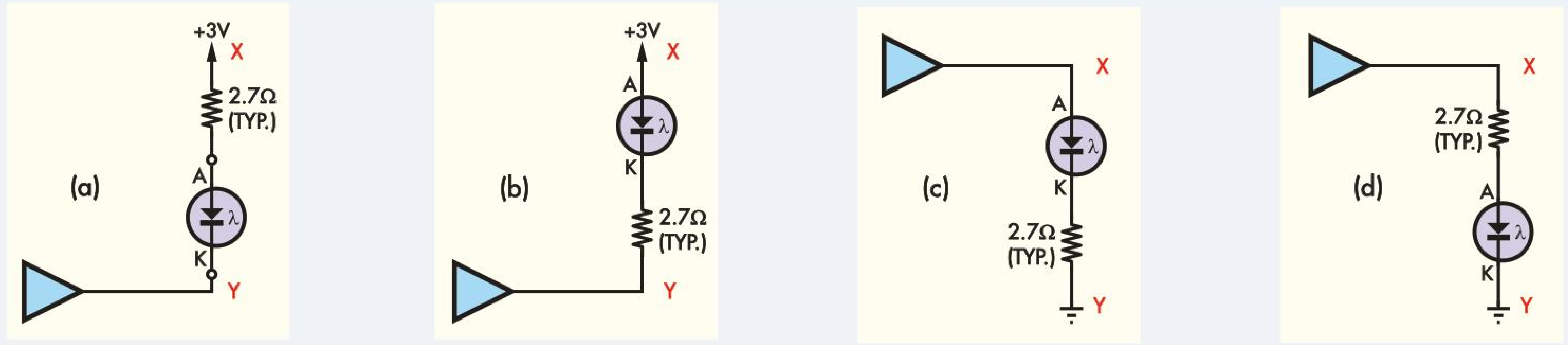


Fig.2: the four possible IR LED driver arrangements in a remote control. The signal drive to the *IR-to-UHF Converter* must be taken from the points labelled 'X' and 'Y' (see text for determining the configuration of your remote).

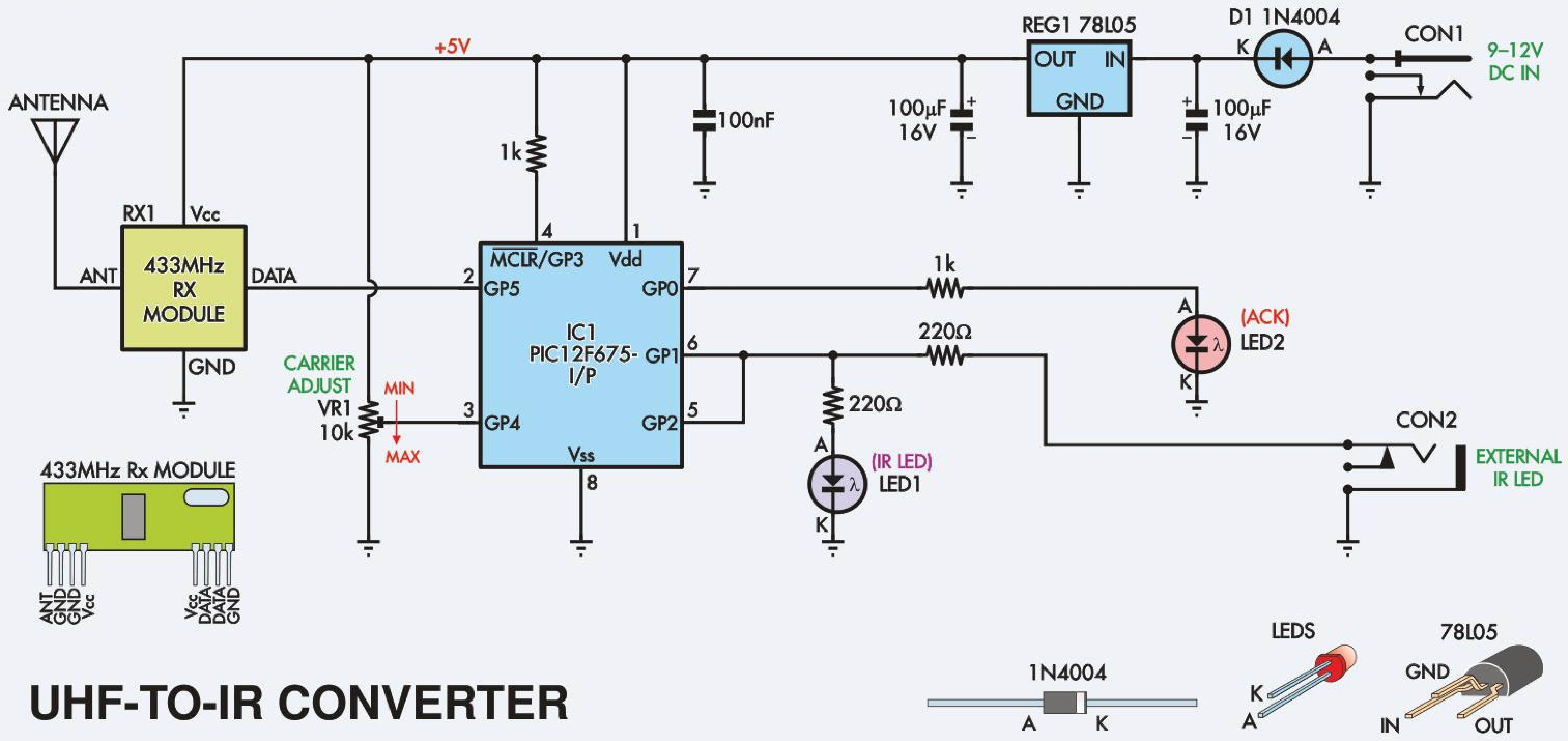

+5V
ANTENNA
RX1
Vcc
ANT
433MHz RX MODULE
DATA
GND
CARRIER ADJUST
VR1 10k
MIN
MAX
1k
MCLR/GP3
Vdd
GP5
GP0
IC1 PIC12F675-I/P
GP1
GP4
GP2
Vss
100nF
100µF 16V
REG1 78L05
OUT IN
GND
D1 1N4004
K A
CON1
9–12V DC IN
1k
220Ω
220Ω
(ACK) LED2
(IR LED) LED1
CON2
EXTERNAL IR LED
433MHz Rx MODULE
ANT GND GND Vcc
Vcc DATA DATA GND
UHF-TO-IR CONVERTER
1N4004
LEDS
78L05
GND
IN OUT

Fig.3: the *UHF-to-IR Converter* circuit picks up the transmitted 433MHz signal using RX1 and feeds it to PIC microcontroller IC1. IC1 in turn drives an infrared LED (LED1) and an acknowledge LED (LED2).

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DYNALINK

At the onset of signal at pin 7, IC1 wakes up and sets its GP1, GP4 and GP5 outputs high (3V) to power up the UHF transmitter (TX1). IC1 also demodulates the 38kHz signal, so that the output at pin 5 is identical to the original modulation on the 38kHz bursts.

TX1 transmits the UHF signal using a 170mm antenna, which is just a length of hook-up wire. After a period of 600ms with no 38kHz signal, power to TX1 is removed with GP1, GP4 and GP5 going low.

Using a microcontroller might seem like overkill for the circuit. However, it was chosen simply because it can be put to sleep and thereby draw negligible current from the remote control's cells. Any other approach, such as using a couple of CMOS timers (eg, 7555), would have much higher current drain than the remote control itself.

UHF-to-IR Converter

The modulated UHF signal needs to be detected and converted back to a stream of infrared pulses to control the appliance being operated. For that we need the separate *UHF-to-IR Converter* referred to above.

The converter circuit is shown in Fig.3 and comprises UHF receiver RX1, another PIC12F675 microcontroller (IC1) and an IR LED (LED1). The whole circuit is powered from 9-12V DC.

The UHF receiver is powered continuously, so that it is ready to receive a transmission from the *IR-to-UHF Converter* in the hand-held remote. With no signal present, the data output from the UHF receiver is just random noise with an amplitude of 5V. In this state, the receiver operates at maximum gain, due to its automatic gain control (AGC).

When a UHF signal is received, the AGC reduces the receiver's sensitivity so that the detected signal is essentially noise-free. This is fed to the GP5 input (pin 2) of PIC micro IC1.

To determine if a signal is valid, IC1 checks for periods where the data line from the UHF receiver is at 0V for at least 8ms. This indicates that the AGC has reduced the sensitivity of the receiver and that a transmission is occurring. The 8ms periods also indicate breaks between successive bursts of 433MHz signal.

IC1 drives the IR LED (LED1) and an Acknowledge LED (LED2) from its GP1, GP2 and GP0 outputs; ie, GP0 drives LED2, while GP1 and GP2 drive LED1. Note that the acknowledge LED does not simply follow the data signal level; it is only intended as a visible confirmation that a valid signal is being received.

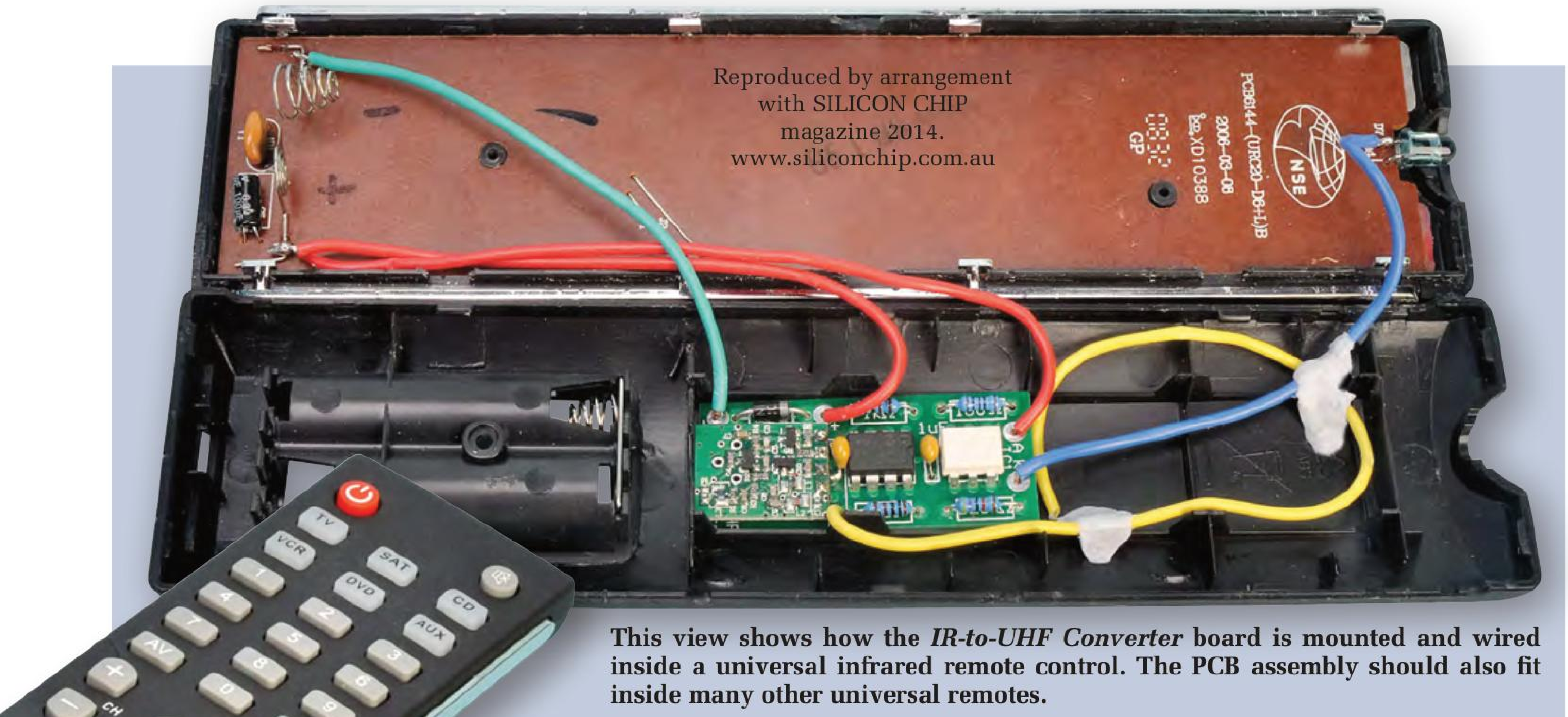
A second output is provided via a 3.5mm jack socket (CON2) for an

Measuring the standby current

How do we measure a standby current of only 12nA? After all, this is far below the current ranges of any digital multimeter.

The procedure is to feed the supply to the circuit via a 100kΩ resistor, but with a switch connected across it to allow the circuit to be powered up normally; it does draw more current at power up. Then, after a second or so when the micro has gone to sleep, the switch is opened and the voltage across the resistor is measured.

For 12nA, the voltage measured across the 100kΩ resistor is 1.2mV.



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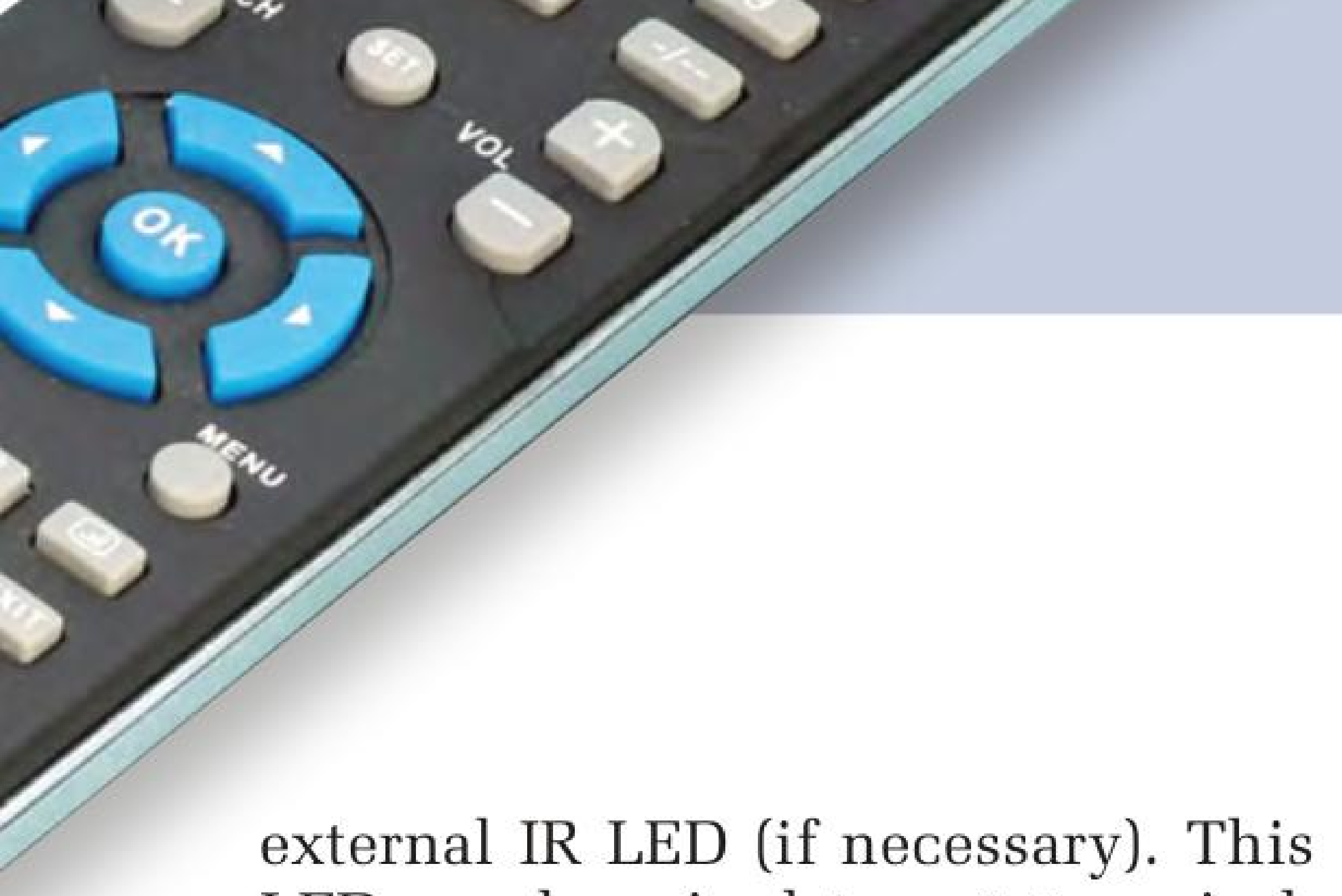
This view shows how the *IR-to-UHF Converter* board is mounted and wired inside a universal infrared remote control. The PCB assembly should also fit inside many other universal remotes.



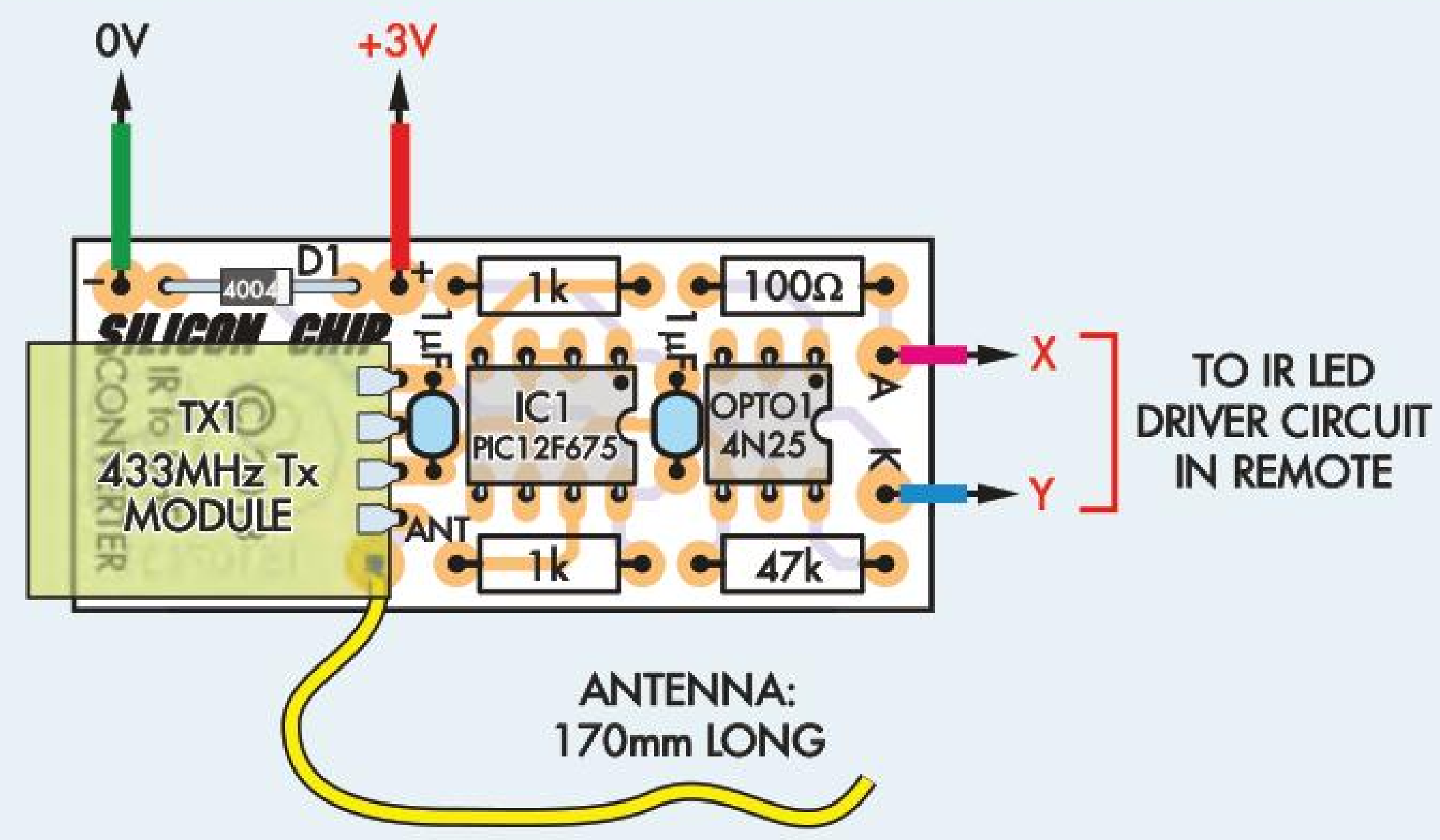


Fig.4: follow this parts layout diagram to build the *IR-to-UHF Converter.* Power comes from the remote's 3V supply, while the input to OPTO1 comes from the remote's IR LED driver circuit (see Fig.2).

Main features and specifications

IR-to-UHF Converter

Transmission range to UHF receiver: >30m

Signal detect delay: 62µs for start and finish

UHF transmitter power down: 600ms from end of signal

Standby current: 12nA typical (12nA measured on prototype)

Operating current: unmodified IR hand-held remote = 10mA; with UHF transmission = 12mA total

UHF-to-IR Converter

Valid transmission: requires 8ms minimum quieting period

Acknowledge LED: 654ms time-out after a valid signal

Modulation frequency adjustment: 33.33-47.66kHz in 10 steps

Current consumption: 50mA during reception / transmission of an IR signal

IR transmission range: typically 2m to appliance receiver

external IR LED (if necessary). This LED can be wired to a 3.5mm jack plug on the end of a cable to allow the LED to be attached or mounted near to the IR receiver of the appliance(s) being operated.

The GP4 input of IC1 monitors the voltage set by trimpot VR1 which is across the 5V supply rail. Its wiper voltage is converted to a digital value within IC1, allowing the IR carrier frequency to be adjusted to suit the particular infrared receiver in the appliance under IR control. The adjustment range is from 33.33kHz to 47.66kHz in 10 steps.

Setting VR1 to its mid position gives 38kHz. Usually, 38kHz is satisfactory but some remotes may require a different carrier frequency to this.

Power is derived from a 9-12V DC plugpack. This is fed in via diode D1 which provides reverse polarity protection. A 78L05 3-terminal regulator then provides a 5V supply for RX1 and IC1.

IR-to-UHF converter assembly

Refer now to Fig.4 for the assembly details of the *IR-to-UHF Converter*. It's built on a PCB available from the *EPE PCB Service,* coded 15107131 and measuring just 20 × 47mm.

Begin by checking the PCB for any faults (rare), then start the assembly by installing the resistors and diode D1. Table 1 shows the resistor colour codes, but you should also check each one using a DMM. Make sure the diode is installed with the correct polarity.

The two capacitors go in next, followed by IC1 and optocoupler OPTO1. Both IC1 and OPTO1 are

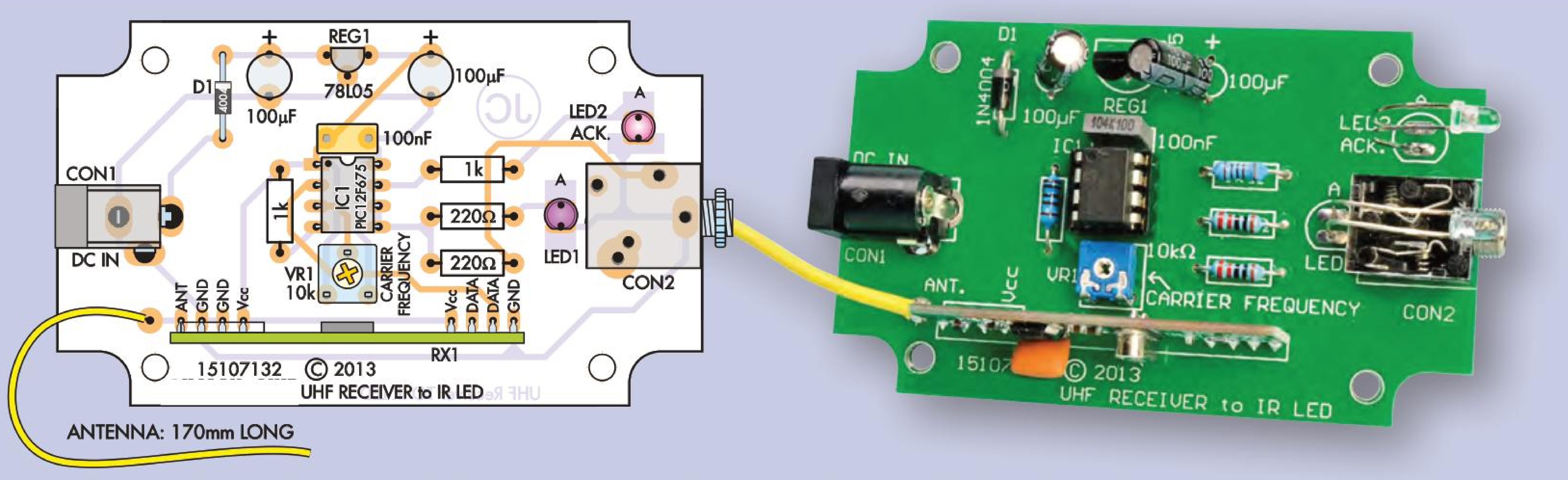

REG1
D1
4004
100µF
78L05
100µF
100nF
LED2 ACK.
A
CON1
1k
IC1 PIC12F675
1k
220Ω
220Ω
A
LED1
DC IN
VR1 10k
CARRIER FREQUENCY
ANT GND GND Vcc
Vcc DATA DATA GND
CON2
RX1
15107132 © 2013
UHF RECEIVER to IR LED
ANTENNA: 170mm LONG
1N4004
REG1
IC1
100nF
10kΩ
VR1
ANT.
Vcc
CARRIER FREQUENCY
LED
LED ACK.
A
CON1
CON2
DC IN
15107
© 2013
UHF RECEIVER to IR LED

Fig.5: this parts layout diagram and the accompanying photo show the assembly details for the *UHF-to-IR Converter*. Trimpot VR1 sets the output IR carrier frequency and should initially be set mid-way to give a frequency close to 38kHz.

soldered directly on the PCB since there is insufficient space in the remote control case to allow sockets to be used.

Follow with the 433MHz UHF transmitter (TX1). This is installed parallel to the PCB, so its leads have to be bent down by 90° before soldering it in place. It should be stood off the PCB slightly so that it is about the same height above the PCB as the ICs. Once it's in, install the 170mm-long antenna wire.

Installation

The first step in the installation is to open the remote control case. For many remotes, a screw within the battery compartment must first be removed, after which the two halves of the case can be carefully prised apart using a wide blade.

It's then just a matter of installing the power supply leads and the leads that run from the remote's IR driver circuitry to the optocoupler. Note that the supply leads must be run around the edge of the case, so that they don't foul other parts when the case is closed. If necessary, notches can be cut into any internal plastic ribs and the wires pressed into these notches.

Make sure that the supply leads connect across the full 3V supply (and not just across one cell) and be sure to connect them the right way around.

As shown in Fig.2, the IR LED can be driven in several different ways, depending on the remote control. This will determine how the 'X' and 'Y' connections from the converter are wired to the remote's IR driver circuitry.

Fig.2(a) and the photos show one connection for the remote. You can determine how the IR LED is connected in your particular remote using a multimeter (DMM).

First, set the DMM to a low ohms range, then short its leads together and check that it shows a 0Ω reading. Clean the multimeter contacts if the reading is above 0.5Ω.

Now, with the two cells removed from the remote, measure the resistance between the anode of its IR LED and the positive battery terminal. The readings are interpreted as follows:

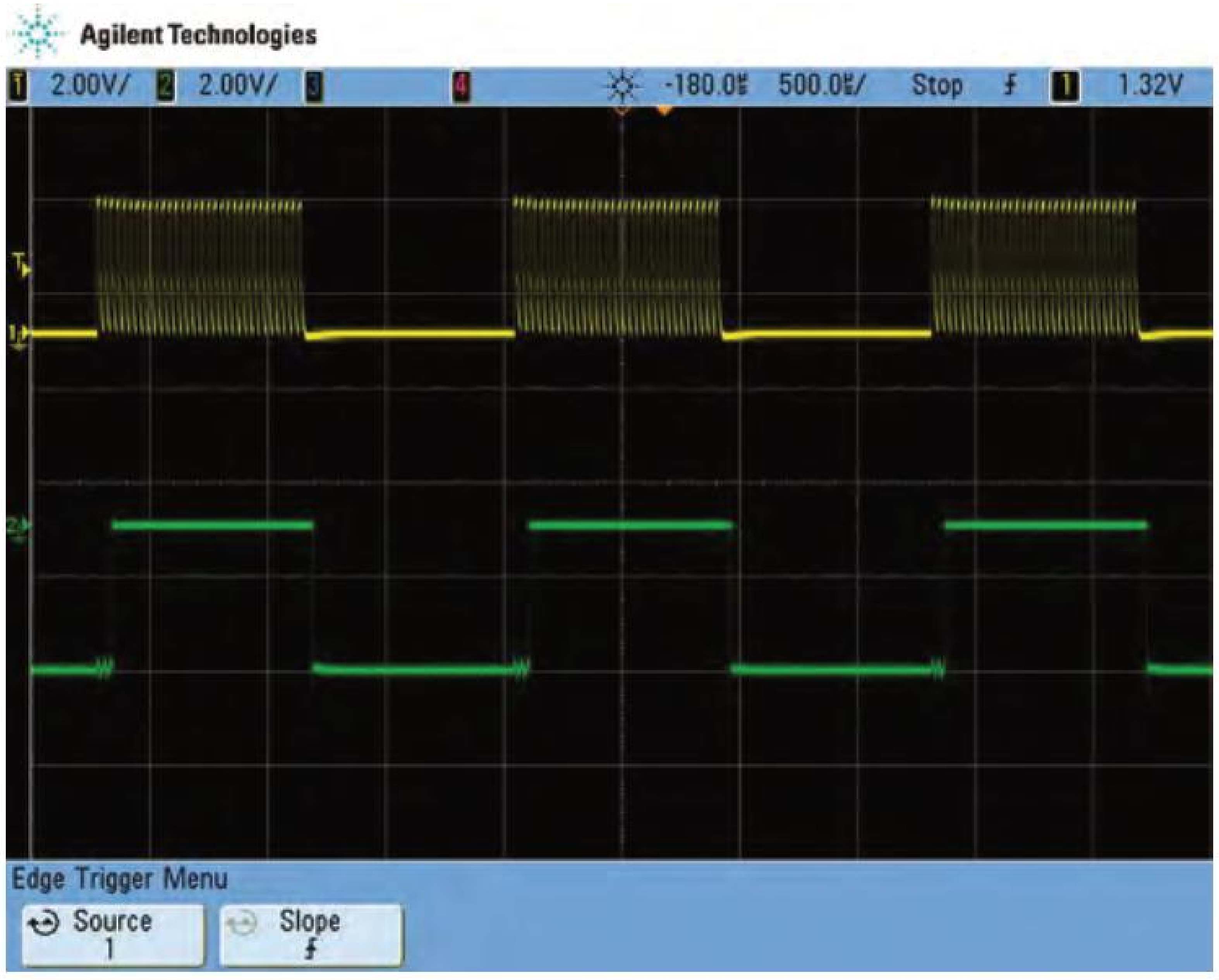

Agilent Technologies
1 2.00V/ 2 2.00V/ 3 4
-180.0µs 500.0µs/ Stop 1 1.32V
Edge Trigger Menu
Source 1
Slope

Fig.6: these waveforms show the operation of the *IR-to-UHF Converter* installed in the remote control. The yellow trace shows the bursts of 38kHz applied to the IR LED. These are coupled via the optocoupler to the microcontroller, which then sends pulses of the same length to turn on the 433MHz transmitter (green trace). Scope timebase speed is 500µs/div.

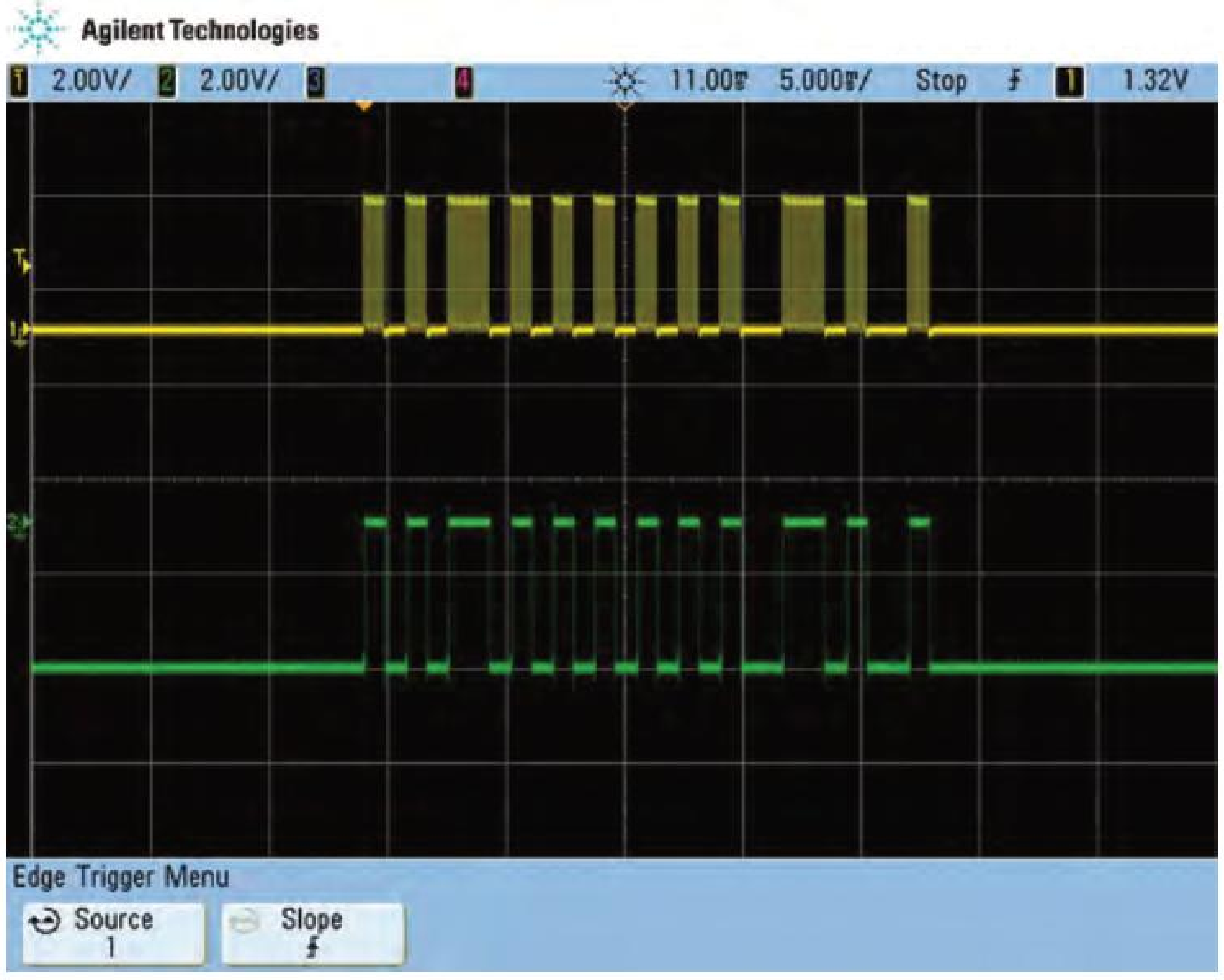
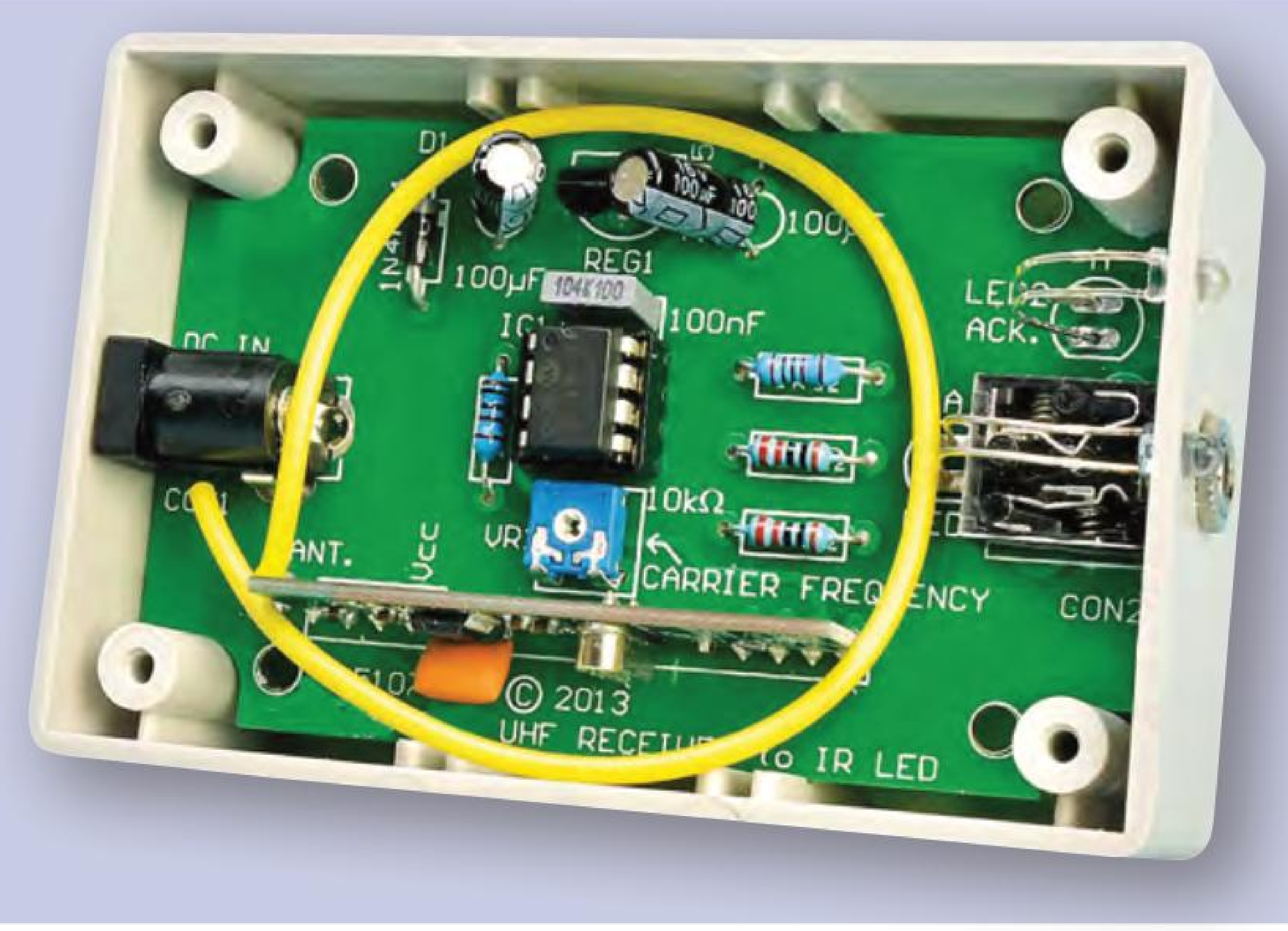

Agilent Technologies
1 2.00V/ 2 2.00V/ 3 4
11.00ms 5.000ms/ Stop 1 1.32V
Edge Trigger Menu
Source 1
Slope

Fig.7: these are the same signals as in Fig.6 but at a timebase speed 10-times slower, at 5ms/div, to show the entire data block being transmitted. Note that there is a delay of about 50µs between the 38kHz bursts and the equivalent pulse fed to the transmitter. This is processing delay in the microcontroller.


D1
1N4
100µF
REG1
100nF
IC1
DC IN
CON1
ANT.
Vcc
VR1
10kΩ
CARRIER FREQUENCY
LED2
ACK.
A
CON2
© 2013
UHF RECEIVER to IR LED

The completed board assembly clips into the integral side ribs in the UB5 plastic case. Note how the IR LED (LED1) is bent across the top of the 3.5mm jack socket.

1) A reading of about 2-3Ω means that circuit is as shown in Fig.2(a) – ie, the limiting resistor is in series between the supply and the IR LED
2) A 0Ω reading between the anode and the positive terminal means a direct connection like that shown in Fig.2(b).

If you get a high resistance reading, check the resistance between the cathode of the IR LED and the negative battery terminal. In this case, the readings indicate the following:

3) A reading of about 2-3Ω means that circuit is as shown in Fig.2(c)
4) A 0Ω reading indicates the arrangement shown in Fig.2(d).

Once you've determined the configuration, it's simply a matter of tracing the connection from the IR LED to its limiting resistor and then running the leads back to the 'X' and 'Y' connections on the converter PCB. In practice, this means that you have to take the drive from across the IR LED and its series limiting resistor. Be sure to get the connections to the remote's drive circuit the right way around, otherwise the converter won't work.

UHF-to-IR Converter assembly

The companion *UHF-to-IR Converter* is built on a PCB coded 15107132, measuring 79 × 47mm, and this is available from the *EPE PCB Service*. This clips into a UB5 plastic utility box measuring 83 × 54 × 31mm and a front-panel label (78 × 49mm) is affixed to the lid.

Fig.5 shows the parts layout on the PCB. Install the resistors and diode D1 first, taking care to ensure that the latter is correctly oriented. The capacitors can then be fitted; make sure that the two 100µF electrolytics go in with the correct polarity.

REG1 can then be mounted, followed by the DC socket (CON1), the 3.5mm jack socket (CON2) and trimpot VR1 (set it mid-way). That done, install the UHF receiver (RX1), making sure it goes in the right way around.

Installing the LEDs

Now for the two LEDs. LED1 must be mounted at full lead length (25mm) so that it can be later bent over and its lens pushed through a hole in the side of the box (above the 3.5mm socket). LED2 is mounted with the top of its lens 20mm above the PCB surface. That's done by pushing it down onto a 15mm cardboard spacer inserted between its leads before soldering it to the PCB. Make sure the LED is oriented correctly, with its anode (longer) lead going to the pad marked 'A'.

Finally, complete the PCB assembly by fitting a 170mm-long antenna wire.

The PCB assembly can now be completed by installing an 8-pin DIL socket for IC1, but do not plug the PIC micro in at this stage. That step comes later, after the power supply has been tested.

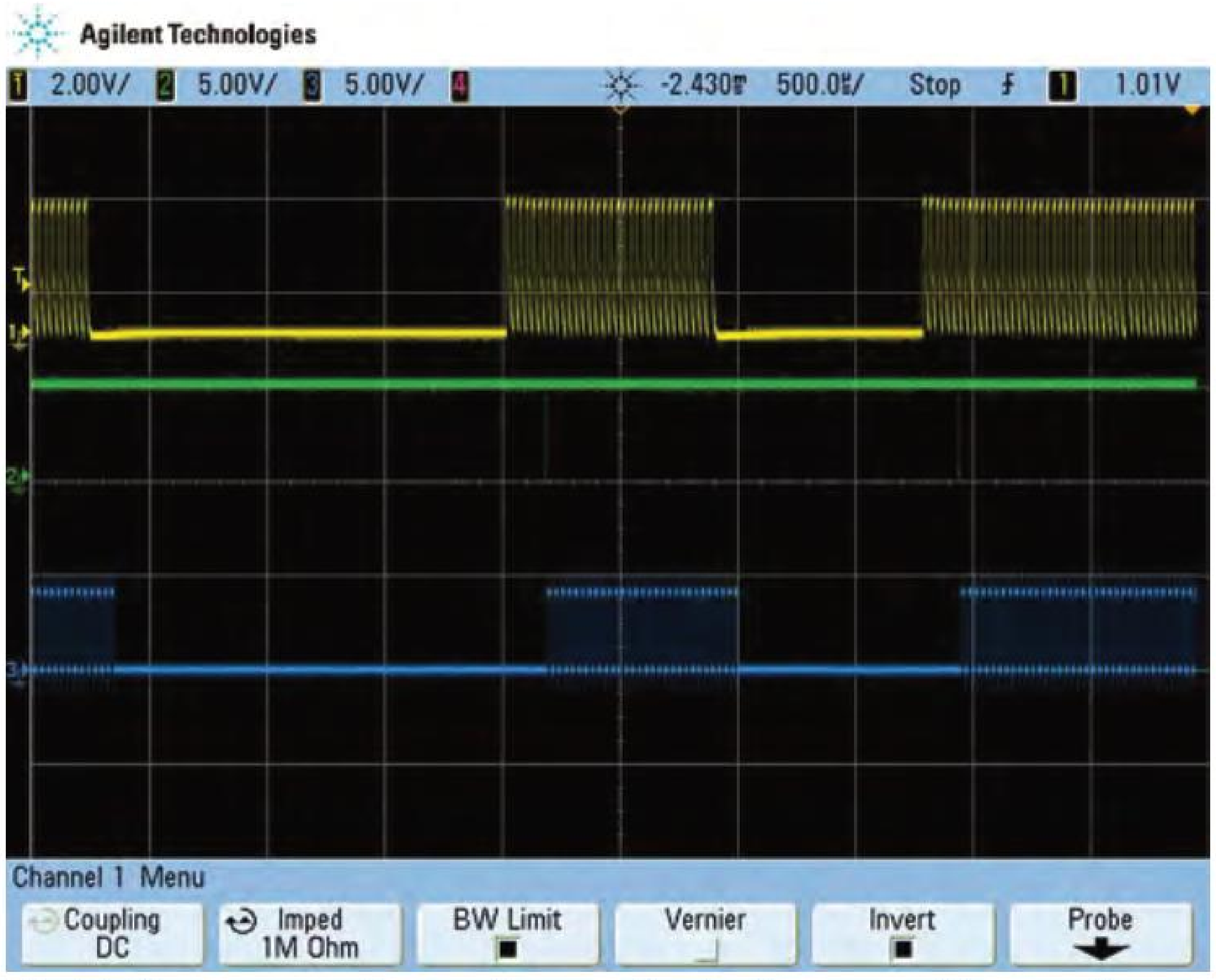

Agilent Technologies
1 2.00V/
2 5.00V/
3 5.00V/
4
-2.430s
500.0µ/
Stop
1.01V
Channel 1 Menu
Coupling DC
Imped 1M Ohm
BW Limit
Vernier
Invert
Probe

Fig.8: these waveforms demonstrate the reception and conversion of the remote control's 38kHz infrared pulses. The yellow trace shows the remote's 38kHz signal, the green trace is the Acknowledge LED signal and the blue trace shows the infrared pulses emitted from the *UHF-to-Infrared Converter*. The scope timebase speed is 500µs/div.

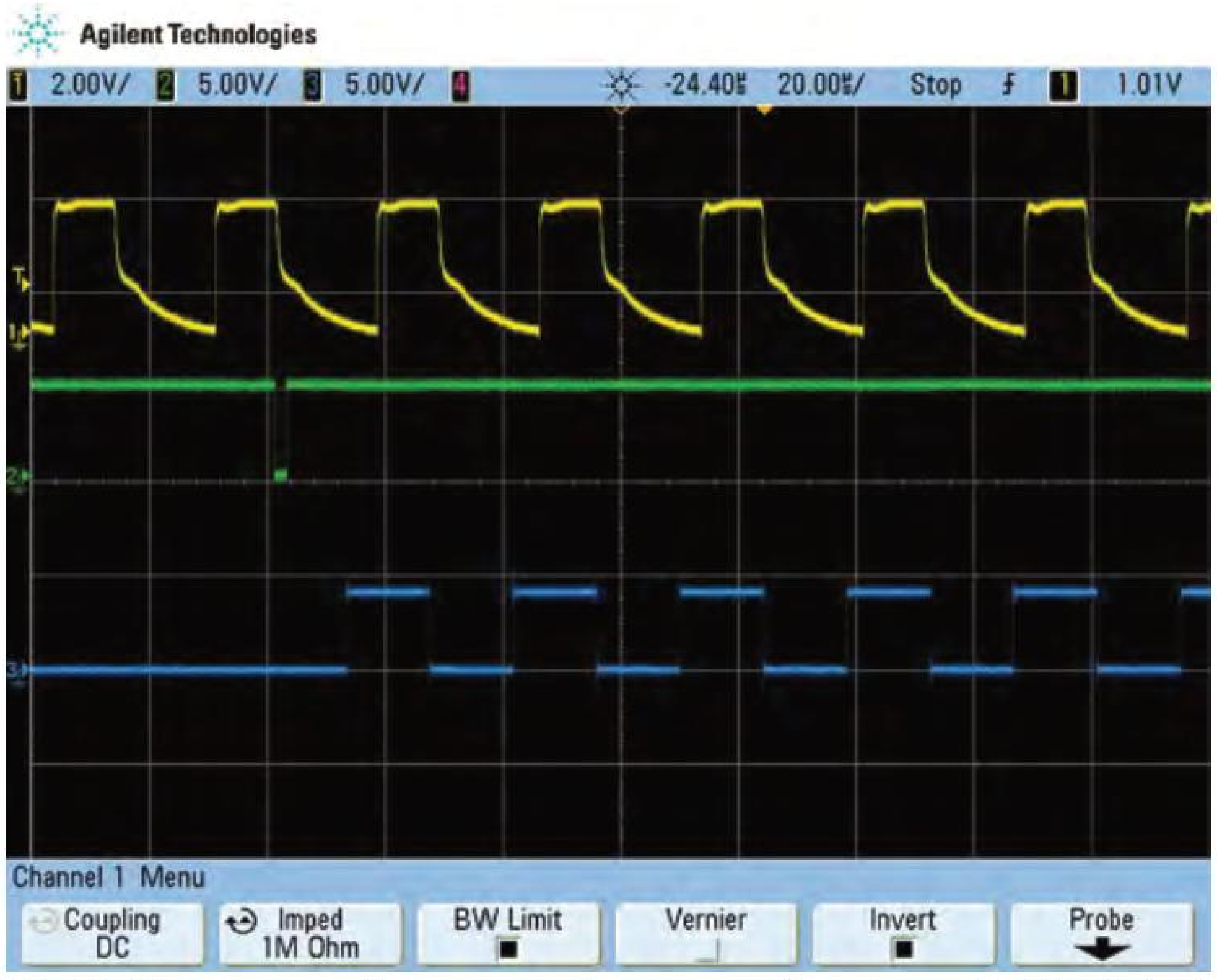

Agilent Technologies
1 2.00V/
2 5.00V/
3 5.00V/
4
-24.40s
20.00µ/
Stop
1.01V
Channel 1 Menu
Coupling DC
Imped 1M Ohm
BW Limit
Vernier
Invert
Probe

Fig.9: these waveforms are the same signals as in Fig.8 but with a timebase speed 10-times faster to show more detail. Note the rounding of the trailing edges of the transmitted 38kHz IR pulses (yellow trace) from the remote control but the much cleaner signal being re-transmitted from the *UHF-to-Infrared Converter* (blue trace).

Modifying The 10-Channel Remote Control Receiver

Simple changes let you install the IR receiver and the 433MHz UHF receiver at the same time for use with both IR and UHF remotes

As good as it is, last month's *10-Channel Remote Control Receiver* can be even more useful when teamed with an IR remote control that's fitted with the tiny *IR-to-UHF Converter*. A couple of modifications to the PCB and some revised software for the microcontroller now allows it to be used with both IR and UHF remote control signals.

By JOHN CLARKE

With the tiny UHF module installed in a remote, you can control the modified *10-Channel Remote Control Receiver* via both IR and UHF signals. When the remote control is within line of sight, the receiver works by relying on IR signals. However, if you are in another room or outside your home, then the link is via UHF and the operation is seamless; there's no need to do anything to change modes.

Alternatively, you could have two remotes to control the *10-Channel Remote Control Receiver*, one unmodified and one with the UHF module installed. For example, the receiver unit could be in your workshop or garage (to operate the doors perhaps) and you could have the option of controlling it using an unmodified IR unit located nearby or via a modified unit with UHF from inside the house.

The circuit changes required to make this possible are quite simple. The original circuit has both the IR signal from IRD1 and the UHF signal from RX1 being applied to the RB3 input of IC1. In practice, this meant that you had to choose between installing either the infrared receiver (IRD1) or the UHF receiver (RX1) and install or remove the SET link accordingly.

By contrast, the revised circuit allows both IRD1 and RX1 to be installed and the micro automatically selects between them. Fig.10 shows the circuit details. As can be seen, IRD1's signal is applied to the RB3 input, while RX1's signal is now applied to the RB2 (SET) input. The microcontroller separately checks for signals from either path and chooses the first valid signal.

Modifying the PCB

To modify the original PCB (available from the *EPE PCB Service*, coded 15106131), first cut the track that leads from the DATA output of the UHF receiver (RX1) at the point where it connects to the track that runs from IRD1's pin 1 output to pin 9 of IC1. Note that this track is on the top side of the PCB. Do not break the connection from pin 1 of IRD1 to pin 9 of IC1.

That done, solder an insulated wire link under the PCB between the DATA output of RX1 and pin 8 of IC1. The SET jumper must be left out.

Both IRD1 and RX1 need to be installed on the PCB for both reception modes to be available. If

Final assembly

The PCB simply clips into the integral ribs of the UB5 case. Before doing this, you need to drill holes in the case ends for the DC socket, the 3.5mm socket and the two LEDs.

The DC socket hole can be drilled first. This is positioned 6.5mm down from the top lip of the base at the left-hand end and is centred horizontally. Start this hole using a small pilot drill to begin with, then carefully enlarge it to 6.5mm using a tapered reamer.

At the other end of the case, the 3.5mm socket hole is also centred horizontally and is positioned 10.5mm down from the lip. Again, use a pilot drill to start it, then enlarge it to 6.5mm. The hole for LED1 is then drilled 3.5mm down from the lip directly above the socket hole. Drill this hole to 3mm, then drill a similar hole for LED2 about 12mm to the right.

The PCB can now be clipped into the slots in the side ribs of the box (push the 3.5mm jack socket into its hole first). Once it's in place, the two LEDs are then bent over and pushed through their respective holes in the adjacent end. Secure the assembly by fitting the nut to the jack socket.

Finally, the front-panel label can be downloaded (in PDF format) from the *EPE* website, printed out on photo paper and affixed to the lid using silicone or some other suitable adhesive. The four corner holes for the case screws are cut out using a sharp hobby knife.

Testing

To test the unit, first check that IC1 has not been installed. That done, apply power and check that there is a 5V

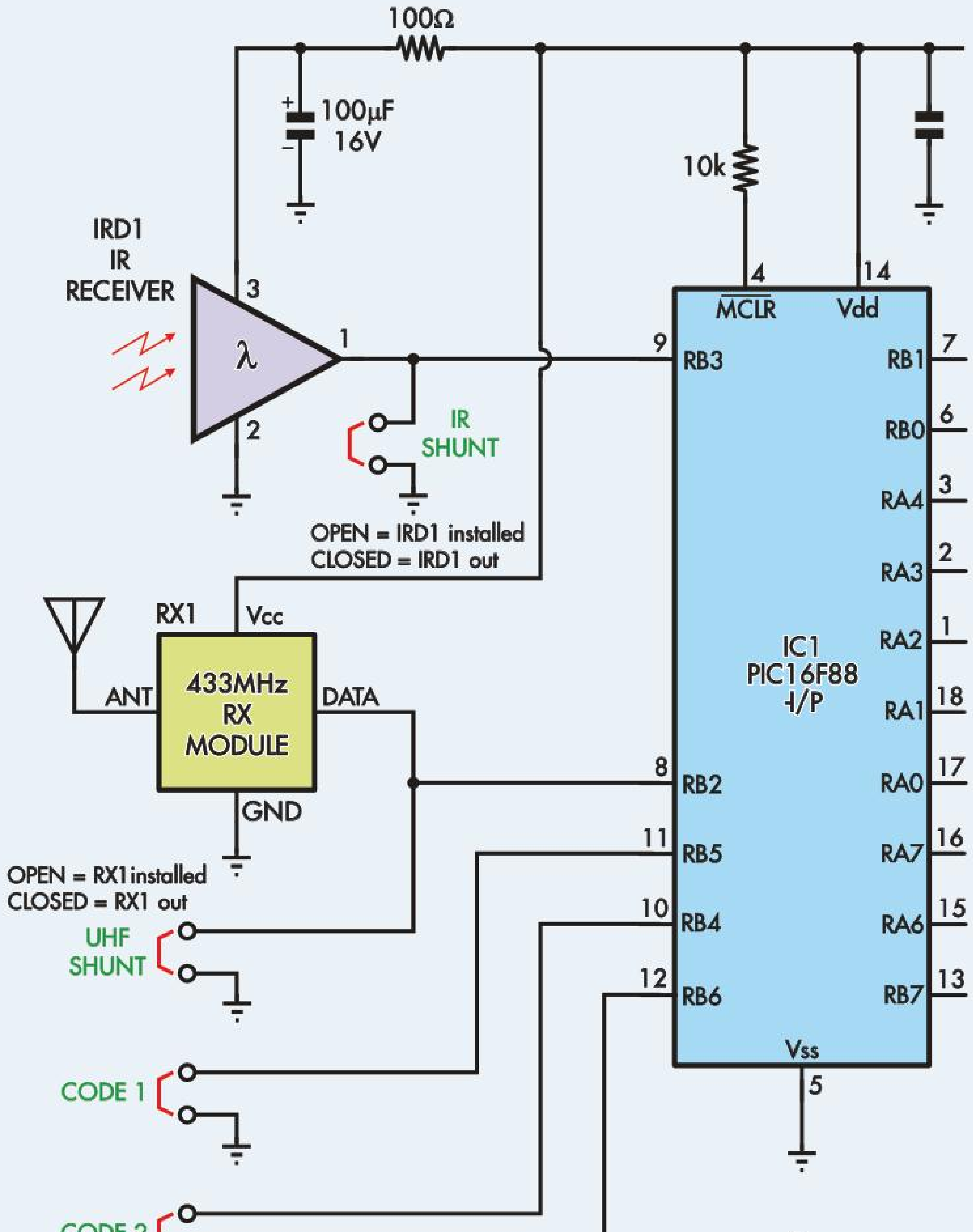

100Ω
100µF
16V
10k
IRD1
IR
RECEIVER
λ
3
1
2
IR
SHUNT
OPEN = IRD1 installed
CLOSED = IRD1 out
RX1
Vcc
ANT
433MHz
RX
MODULE
DATA
GND
OPEN = RX1 installed
CLOSED = RX1 out
UHF
SHUNT
CODE 1
CODE 2
4
14
MCLR
Vdd
9
RB3
RB1
7
RB0
6
RA4
3
RA3
2
IC1
PIC16F88
-I/P
RA2
1
RA1
18
8
RB2
RA0
17
11
RB5
RA7
16
10
RB4
RA6
15
12
RB6
RB7
13
Vss
5
CODE1 & CODE2 OUT = TV
CODE1 IN, CODE2 OUT = SAT1
CODE1 OUT, CODE2 IN = SAT2
CODE1 & CODE2 IN = CD PLAYER
1k
A
ACK
λ
K
LED10

Fig.10 (above): the revised front-end circuit for the *10-Channel Remote Control Receiver*. The outputs from IRD1 and RX1 are now fed to IC1 on separate inputs in IC1 and the micro automatically selects between them.

you only install one of these, the unused input at pin 8 or pin 9 must be tied to ground. So, if IRD1 is out of circuit, bridge pins 1 and 2 of IRD1's pads. If RX1 is out of circuit, install the SET jumper.

Modified PCB

A modified PCB, code 15106133, is also available that includes the necessary track modifications.

Fig.11 shows the parts layout for this PCB. If both IRD1 and RX1 are installed, then both the IR SHUNT and UHF SHUNT jumpers are left out. If either IRD1 or RX1 is left out, then its associated shunt jumper must be installed.

Revised software

The revised software for the microcontroller is coded 1510613B. It must be used regardless as to whether you modify the original PCB or use the revised PCB design. Note: this software is not suitable for use with the original unmodified PCB.

The new software is available for download from the *EPE* website (**www.epemag.com**), while the revised PCB can be purchased from the *EPE PCB Service*.

Fig.11 (below): the parts layout for the modified PCB. Be sure to install the relevant SHUNT jumper if its receiver is left out of circuit (see text).

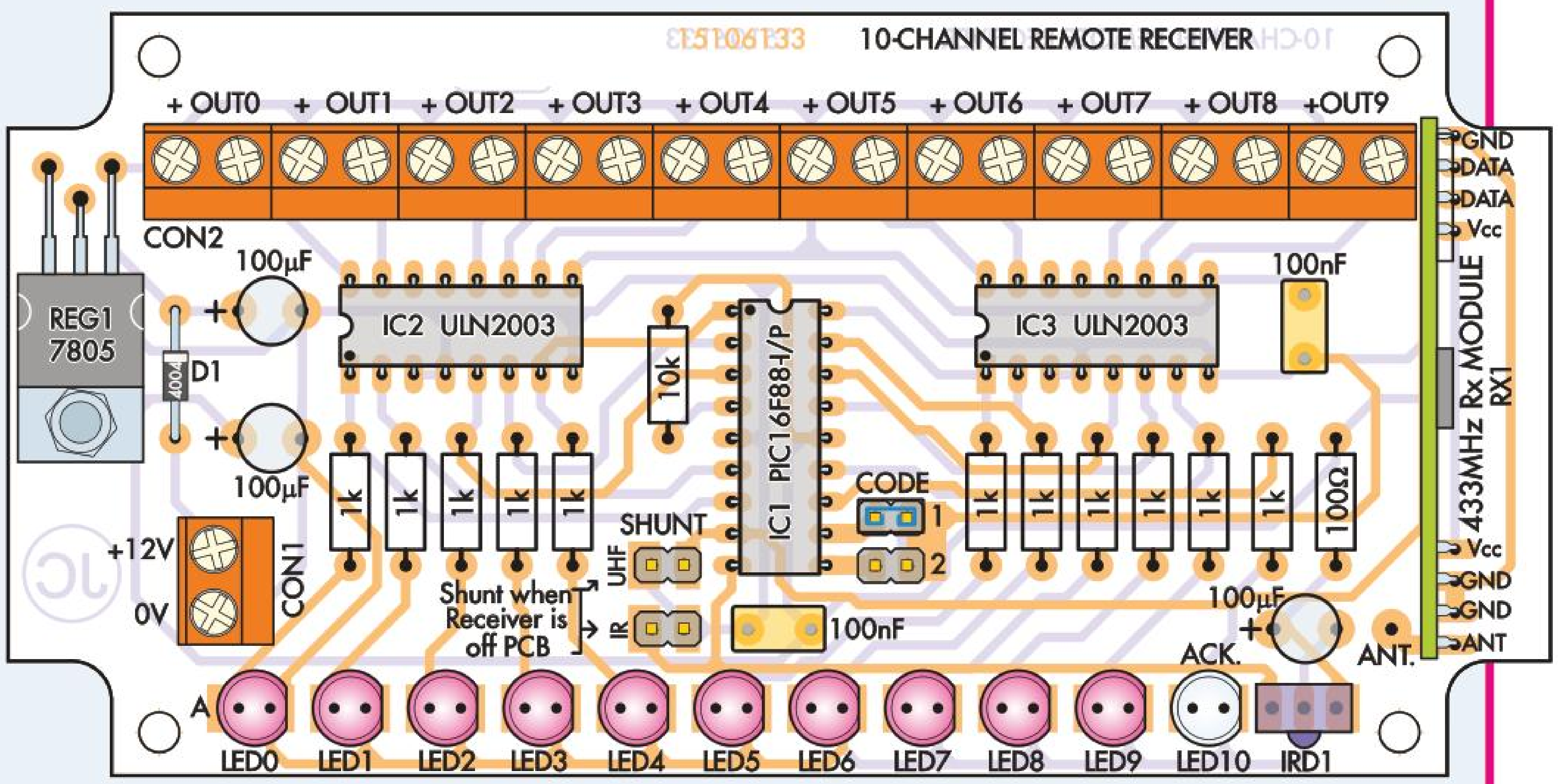

15106133
10-CHANNEL REMOTE RECEIVER
+ OUT0
+ OUT1
+ OUT2
+ OUT3
+ OUT4
+ OUT5
+ OUT6
+ OUT7
+ OUT8
+ OUT9
CON2
100µF
100nF
REG1
7805
IC2 ULN2003
IC3 ULN2003
D1
4004
10k
IC1 PIC16F88-I/P
100µF
1k
100Ω
CODE
1
2
SHUNT
UHF
IR
Shunt when Receiver is off PCB
100nF
+12V
0V
CON1
100µF
ACK.
ANT.
GND
DATA
DATA
Vcc
Vcc
GND
GND
ANT
433MHz Rx MODULE
RX1
A
LED0
LED1
LED2
LED3
LED4
LED5
LED6
LED7
LED8
LED9
LED10
IRD1

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	1	47kΩ	yellow violet orange brown	yellow violet black red brown
☐	4	1kΩ	brown black red brown	brown black black brown brown
☐	2	220Ω	red red brown brown	red red black black brown
☐	1	100Ω	brown black brown brown	brown black black black brown

supply between pins 1 and 8 of the IC socket. If you don't get 5V, check the supply polarity and that D1 and REG1 are installed the right way around.

Assuming you do get 5V, switch off and install IC1 with its notched end towards the adjacent 100nF capacitor. Now reapply power and check that the red acknowledge LED flashes when the remote control buttons are pressed.

The next step is to set the universal remote control so that it produces the correct code for your appliance. That done, test it without the *UHF-to-IR Converter* (ie, turn the converter off) first to ensure the appliance can be controlled using IR signals only.

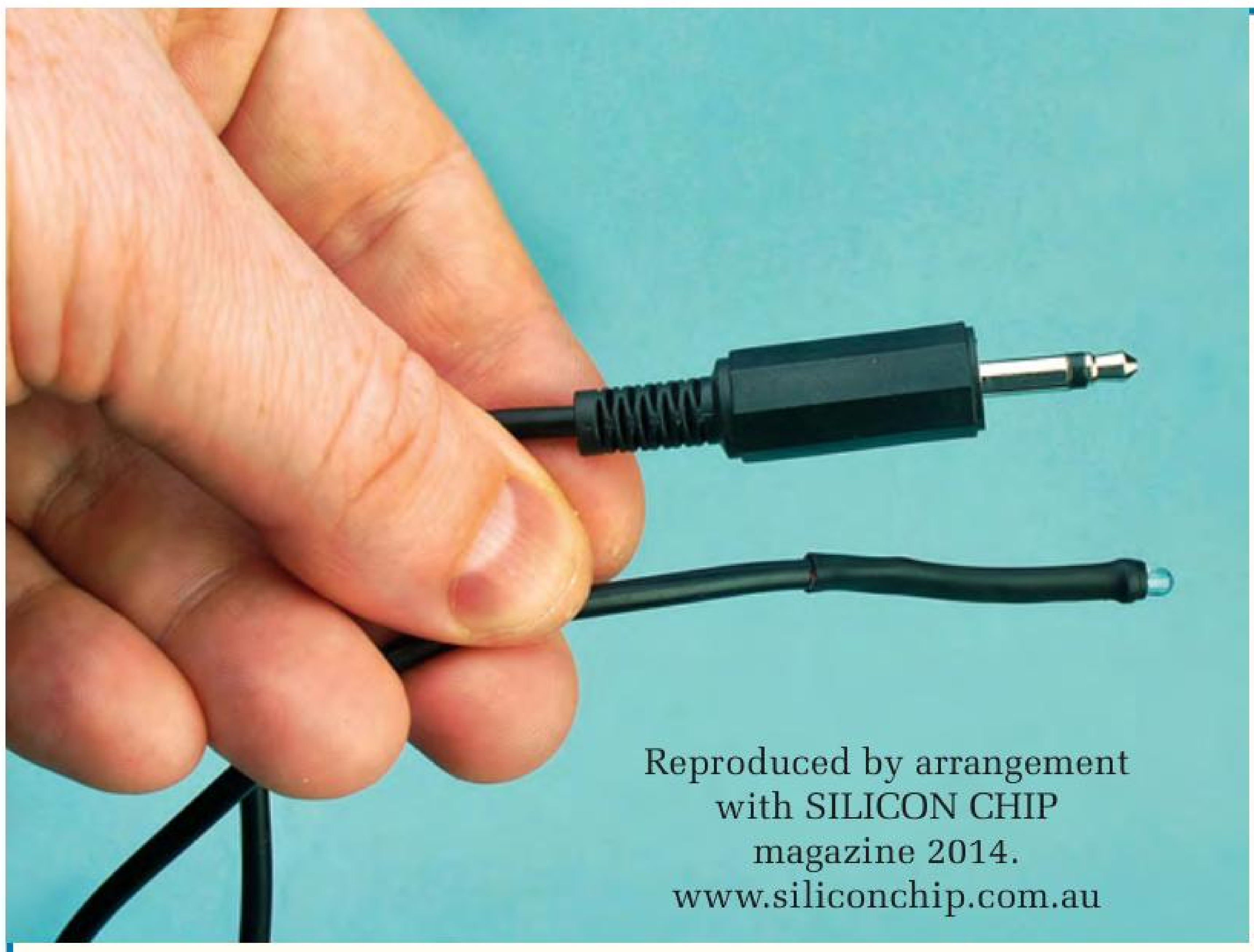
Once that works correctly, the remote control can be tested with the *UHF-to-IR Converter* unit. Note that the converter's IR LED should be pointed in the general direction of the appliance to be controlled.

To test it, power up the *UHF-to-IR Converter*, cover the IR LED on the remote with a finger and check that the appliance can be controlled via the UHF radio link. If it doesn't work, adjust VR1 as you operate the remote control until the appliance responds. Usually, setting VR1 mid-way (corresponding to a carrier frequency of 38kHz) will be suitable.

If it still doesn't work, the optocoupler in the *IR-to-UHF Converter* in the remote may not be working correctly due to insufficient drive. In that case, reduce the 100Ω resistor in series with pin 1 of OPTO1. A value of between 22Ω and 47Ω should do the job.

Once it's operating correctly, try using the remote to control the appliance from another room. You should get a free-air range of 30 metres or more, but the range will be less than this inside a house, depending on any obstacles (walls, etc) between the remote and the *UHF-to-IR Converter*.

Finally, note that the IR receivers in many appliances are so sensitive that they will respond to IR signals that are bounced off the walls or the ceiling of the room. So experiment before going to the trouble of making up the extension cable if you can't aim the IR LED in the *UHF-to-IR Converter* directly towards the appliance.



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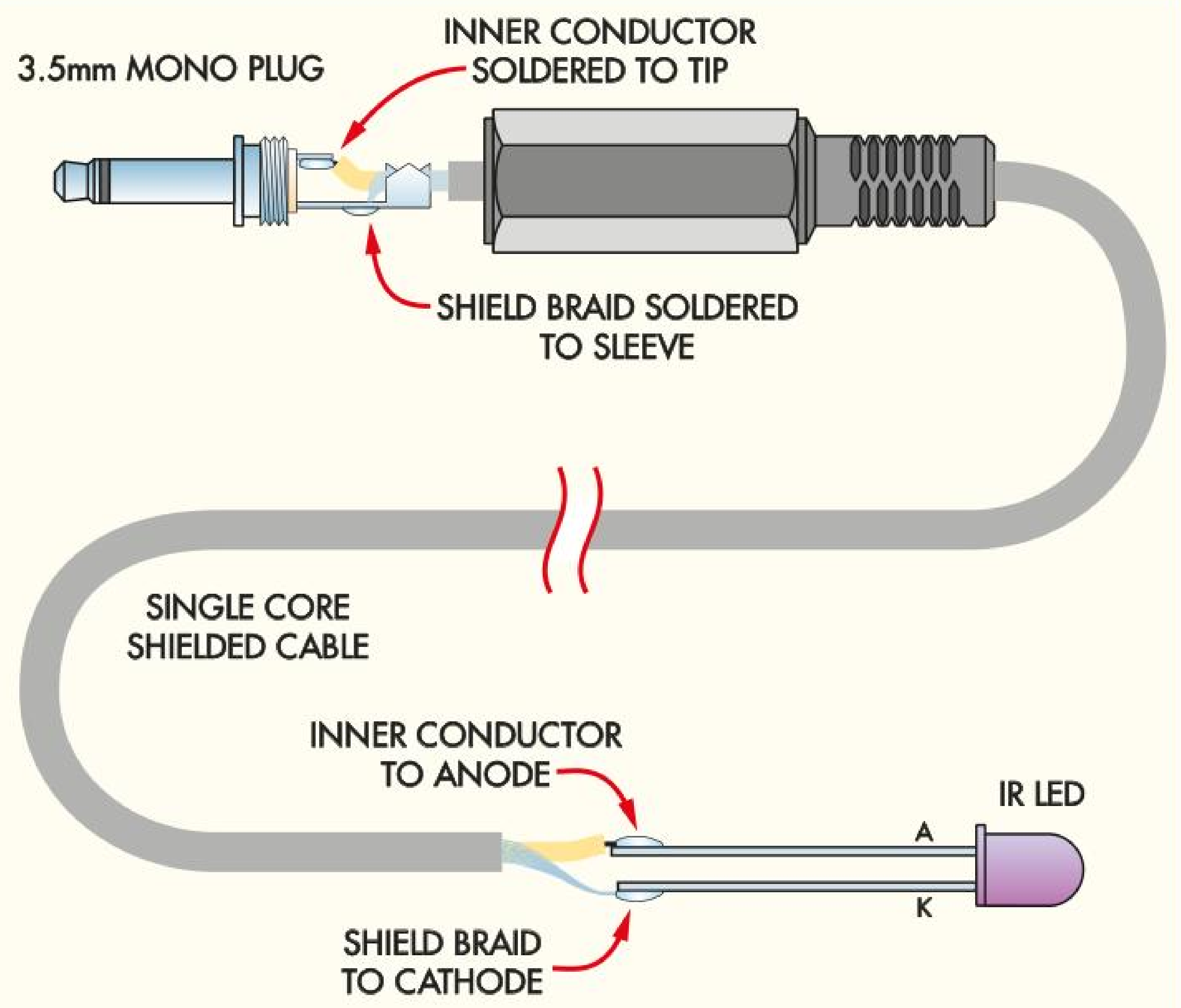
3.5mm MONO PLUG
INNER CONDUCTOR SOLDERED TO TIP
SHIELD BRAID SOLDERED TO SLEEVE
SINGLE CORE SHIELDED CABLE
INNER CONDUCTOR TO ANODE
IR LED
A
K
SHIELD BRAID TO CATHODE

Fig.12: here's how to make an IR LED extension cable if you need one.

Making an IR LED extension cable

Depending on how your gear is arranged, you may also want to make up a cable with a 3.5mm jack plug at one end and an external IR LED at the other. Fig.12 shows the details. You will need to use a suitable length of single-core shielded cable, while the LED leads should be insulated from each other using heatshrink tubing.

A larger piece of heatshrink can then be used to cover the end of the cable, both LED leads and part of the lens.

Parts List

IR-to-UHF Converter

1 infrared remote control
1 double-sided PCB, available from the *EPE PCB Service* code 15107131, 20mm × 47mm
1 433MHz transmitter (TX1)
1 170mm length of yellow light duty hook-up wire
1 200mm-length red hook-up wire
1 200mm-length green hook-up wire
1 200mm-length blue hook-up wire

Semiconductors

1 PIC12F675-I/P programmed with 1510713A.hex (IC1)
1 4N25 or 4N28 optocoupler (OPTO1)
1 1N4004 1A diode (D1)

Capacitors

2 1µF monolithic ceramic (MMC)

Resistors (0.25W, 1%)

1 47kΩ 1 100Ω
2 1kΩ

UHF-to-IR Converter

1 double-sided PCB, available from the *EPE PCB Service,* code 15107132, 79 × 47mm
1 UB5 box, 83 × 54 × 31mm
1 front panel label, 78 × 49mm
1 433MHz receiver (RX1)
1 PCB-mount 2.5mm DC socket
1 3.5mm PCB-mount switched jack socket
1 DIL8 IC socket
1 170mm-length of light-duty hookup wire
1 10kΩ miniature horizontal trimpot (VR1)

Semiconductors

1 PIC12F675-I/P programmed with 1510713B.hex (IC1)
1 78L05 regulator (REG1)
1 1N4004 1A diode (D1)
1 3mm IR LED (LED1)
1 3mm red LED (LED2)

Capacitors

2 100µF 16V PC electrolytic
1 100nF MKT polyester

Resistors (0.25W, 1%)

2 1kΩ 2 220Ω

Optional

1 3.5mm mono jack plug
1 1m length single core screened cable
1 3mm IR LED
1 100mm length 3mm-diameter heatshrink tubing

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Want seven ways to relax? Try our PIC-controlled mind machine!

PIC MIDI Sustain Pedal
Add sustain and glissando to your MIDI line-up with this inexpensive PIC-controlled effects unit

PIC-based MIDI Handbells
Ring out thy bells with merry tolling – plus a MIDI PIC-up, of course!

EPE Mood PICker
Oh for a good night's sleep! Insomniacs rejoice – your wakeful nights could soon be over with this mini-micro under the pillow!

PIC Micro-Probe
A hardware tool to help debug your PIC software

PIC Video Cleaner
Improving video viewing on poorly maintained TVs and VCRs

PIC Graphics LCD Scope
A PIC and graphics LCD signal monitor for your workshop

PIC to Printer Interface
How to use dot-matrix printers as data loggers with PIC microcontrollers

PIC Polywhatsit
A novel compendium of musical effects to delight the creative musician

PIC Magick Musick
Conjure music from thin air at the mere untouching gesture of a fingertip

PIC Mini-Enigma
Share encrypted messages with your friends — true spymaster entertainment

PIC Virus Zapper
Can disease be cured electronically? Investigate this controversial subject for yourself

PIC Controlled Intruder Alarm
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Unsung heroes

TechnoTalk

Mark Nelson

Computing is full of well-known heroes – Alan Turing, Bill Gates, Clive Sinclair and Steve Jobs spring easily to mind, even to those not particularly interested in computers. But when it comes to electronics the choice is narrower; Marconi might get some public recognition but could many people name what Fleming, De Forest, Bardeen, Brattain and Shockley pioneered? Mark Nelson waves the flag for forgotten pioneers.

IT WAS A RECENT ARTICLE IN one of the trade magazines that got me thinking. It stated that French physicist Edmond Becquerel was the first to demonstrate the photovoltaic effect, as long ago as 1839, when he built the world's first photovoltaic cell. If the name Becquerel rings a bell at all, no doubt it's only as a unit of radioactivity and this, ironically, is named after Edmond's son Henri, who was first to discover spontaneous radioactivity. And in just the same way, most other electronics innovators received no credit for their inventions and developments. Take Paul Eisler and John Szabadi for instance; both of them totally revolutionised the manufacturing of electronic products, but I suspect few readers will have heard of them, even if I admit that Szabadi later changed his name to Sargrove. So let's take a moment to give credit where it's due.

Eisler and Szabardi

Both of our first pair of unsung heroes had European backgrounds. Dr Paul Eisler was born in Austria in the year 1907, while John Sargrove entered this world a year earlier, born in London of Hungarian parents and educated in Budapest. Each of them made their claim to fame in England. It may surprise you to know that Eisler devised and patented the printed circuit board, while Sargrove invented and patented another form of PCB, together with methods of automating the production of radios and television receivers.

Brilliant inventors, poor businessmen

Eisler was Jewish and the anti-Semitism prevailing in the 1930s meant he was unable to find an engineering job in Vienna. After working in Serbia for a while, he came to London in 1936 to sell his patents on graphical sound recording and stereoscopic television. In his spare time he devised a crude printed circuit on which he built a radio and five years later he arranged with a company (known today as Technograph Microcircuits Ltd) to invest in his printed circuit idea (but at the cost of losing his rights to the invention). His process was first adopted in the US for war work and was used all over the world after the end of hostilities. Unfortunately for both Technograph and Eisler, very few other firms acknowledged the patents or even bothered to license them. Subsequently, Eisler successfully patented numerous other electrical and electronic inventions, but was again less fortunate in their commercialisation.

Where would electronics be without the ubiquitous PCB? But who invented it?

Sargrove was equally unlucky with his ingenious ideas. While working for the British subsidiary of the Hungarian Tungsram lamp and radio valve company in 1936 and 1937 he came up with the idea of spraying metal onto a piece of blank circuit board to create resistors, capacitors, inductors and the tracks between them. Essentially, it was an early form of thick-film hybrid technology, with larger components such as valves and electrolytic capacitors fixed separately into drilled holes. After the war he devised an automation system that could produce radio sets (and later TVs) on a production line basis at a rate of three radios a minute. Unfortunately, reliability was less than perfect, while assembly workers saw the system as a threat to their jobs. Financial backing waned and Sargrove Electronics Ltd went into liquidation.

More ignored inventors

Do you use a 'scope or amateur radio equipment? If so, you must be familiar with the humble BNC connector. But you probably don't know why it carries this odd name. Ignore those misinformed people who tell you it's a British Naval or Bayonet Nut connector; it's nothing of the sort. The B does indeed stand for Bayonet but N and C stand for the names of Neill and Concelman, the two Americans who devised the connector during World War Two.

BNC development

Back in the 1930s, when VHF radio was undergoing rapid development, the frequencies above short wave were generally called 'ultra-short wave' (USW) or 'ultra-high frequency' (UHF). It's for that reason that the well known UHF or PL-259 connector got its name, invented by E. Clark Quackenbush, an engineer working for the American Phenolic (Amphenol) Corporation in the USA. It was robust and functional (CBers and some radio hams still use it today) but its impedance was closer to 30Ω than the 50Ω of most RF cable, causing signal degradation in sensitive applications where every last millivolt of signal mattered.

US radio ham Peter Norloff (KG4OJT) takes up the story now, according to him: 'During WW2, radar required a better connector and two designs followed. The first attempted to make a connector look like a piece of 50Ω cable; this was designed by Paul Neill at the Bell Laboratories and was known as the type N connector. [Amphenol engineer] Carl Concelman noticed, however, that there was a small bit of inductance where the centre pins of the N connector met. By changing the position of the dielectric used to fill the connector he was able to introduce some reactive cancellation and [the resulting] type C connector allowed it to be used well into the gigahertz region.

Shortly after this, Neill and Concelman cooperated on the design of a miniature bayonet locking connector. This combined Neill's mechanical design with Concelman's reactive dielectric and his twist-on locking ring. The Bayonet Neill Concelman (BNC) connector had arrived. Because of the noise generated by the BNC connectors under extreme vibration, Neill and Concelman worked on a threaded version. The Threaded Neill Concelman (TNC) was developed in the late 1950s.'

And after that, there's not a lot more to say other than TNC connectors are still used on some mobile and cellular radio installations on board vehicles.

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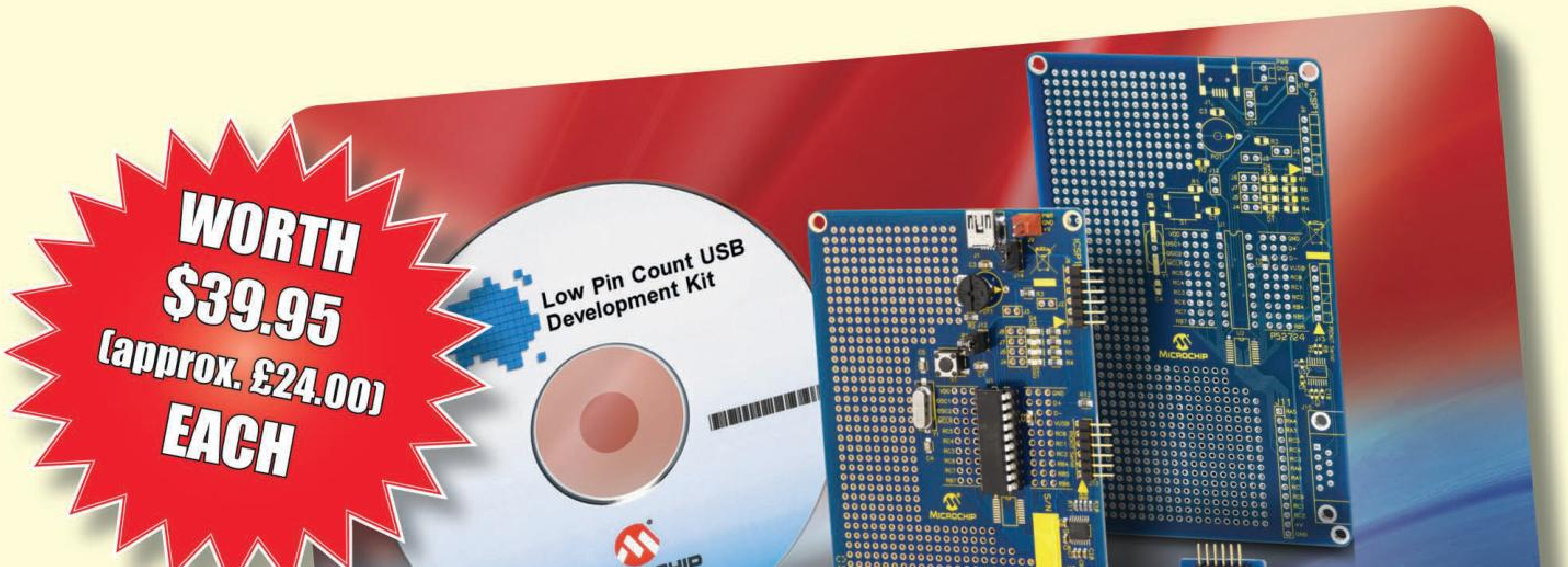
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Bird song – without the mess!

PCBirdies

Ever wished you could have beautiful birdsong in your home, without having to own a live caged bird? With PCBirdies, you can have the luxury of not one, but two singing birds. You won't have to buy a cage or even bird seed. . . and best of all, there's no mess to clean up!

It can be very calming and relaxing to have bird song in your home. In fact, when people have heard this project, without knowing the technicalities, they have found it charming.

PCBirdies will sing from time to time, at random intervals so it (they?) can pipe up unexpectedly at any time during the day, which can be a pleasant diversion. You can hear a few samples of its song on our website.

PCBirdies is (are?) housed in a small plastic box. This might sound a bit cruel but it is entirely happy to be there and we can assure concerned readers that no birds were harmed or put under stress during the development of this project. In fact, as the proverb states, 'A bird in the hand is worth two in the bush'.

Inside the box are two piezo transducers that produce sounds which simulate those of two separate birds. So it might be said that PCBirdies is better than two in the hand.

PCBirdies is powered from a 3V lithium button cell and employs two microcontrollers, each one driving its own piezo transducer.

Specification

Power	3V from a CR2032 lithium cell
Current	0µA when switched off, 1.8µA per IC during periods of silence 735µA per IC while chirping
Sounds	Selection 1 – typical canary sound Selection 2 – Fife canary Selection 3 – various individual phrases Selection 4 – medley of the first three.

Arguably, PCBirdies sounds similar to a canary, but we should state at the outset that a typical canary's song is more varied and they typically sing for much longer periods (their songs can last up to several minutes at a time).

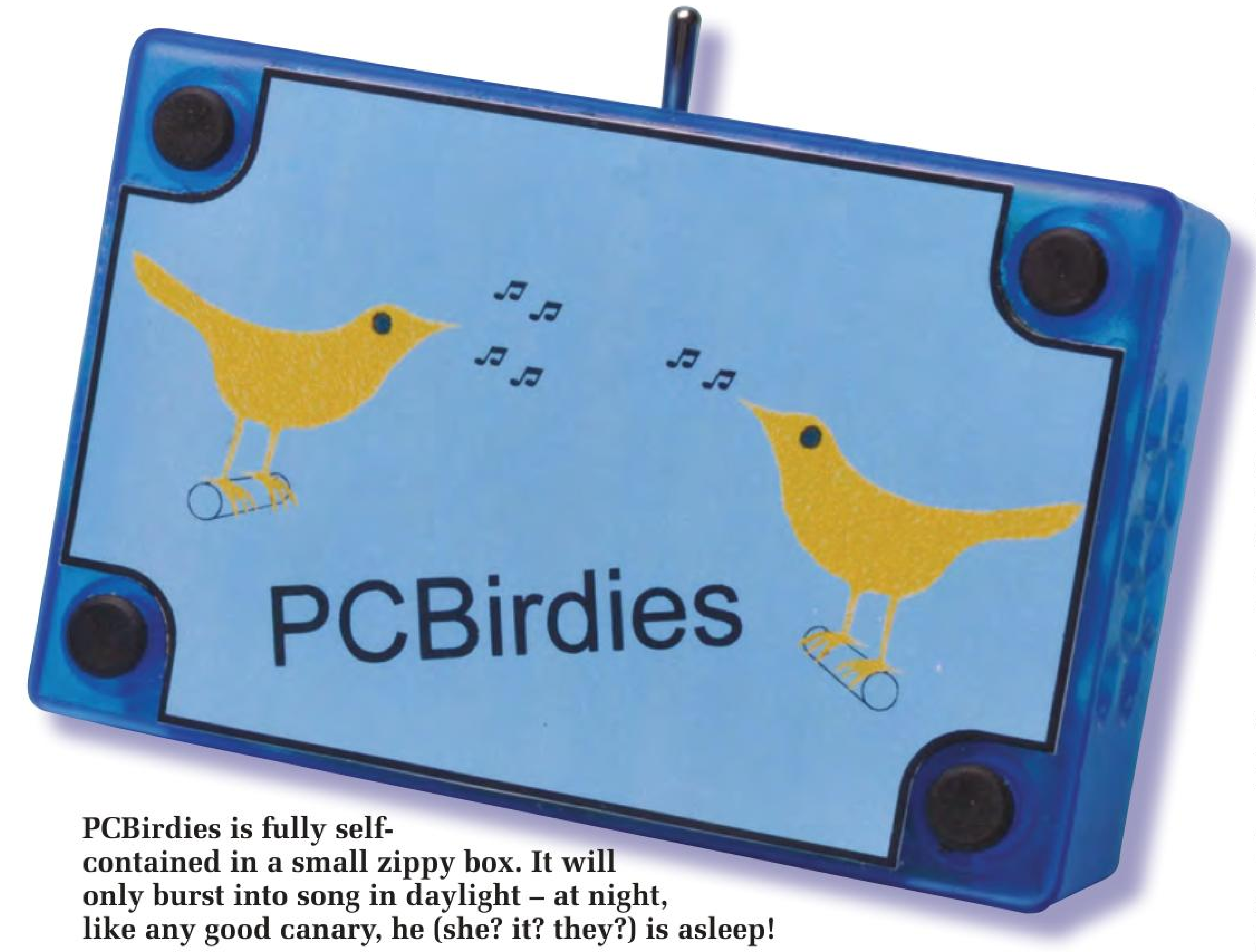
By JOHN CLARKE

But then again, they may go for hours or days without singing at all. PCBirdies, on the other hand, can be guaranteed to sing for your pleasure many times during the day, at seemingly random intervals.

Canary songs consist of a series of chirps, tweets, trills and warbles, and they seldom repeat the same sequence twice. PCBirdies' songs also consists of chirps, tweets, trills and warbles, but its songs are much shorter, typically lasting for about eight seconds.

PCBirdies gives the option to change the canary sound from one type to another. (Try doing that with a real bird). Each selection imitates typical canary sound phrases. Song A is a typical canary and Song B simulates a Fife canary. Song C is a selection that comprises various single phrases of these birds. The fourth selection comprises a medley of all the above played over time.

PCBirdies sings at random. Each



PCBirdies is fully self-contained in a small zippy box. It will only burst into song in daylight – at night, like any good canary, he (she? it? they?) is asleep!

song is repeated between two and 27 times with a 2.4 to 17-second gap between them. There is an extended gap between each series of repeated songs and this is between 80 seconds and 9 minutes.

PCBirdies only sings during daylight or under artificial light – an LDR (light-dependent resistor) senses the ambient light level.

The 'birds' sing in and out of unison to simulate two separate birds. The two birds are re-synchronised at the end of a darkness period and also at the end of the extended gap period.

Note that PCBirdies does not simply play sampled segments of real canary songs. Rather, it simulates the bird song by varying the frequency, volume and length of bursts of pulse trains applied to the piezo.

The volume is adjusted by changing the pulse width of signals applied to the piezo transducers. Narrow pulses give low volume while wider pulses give more volume. Maximum pulse width equates to a pulse duty cycle of 50%.

Each chirp starts with a minimum pulse width, increasing to the required volume level over time. Similarly when a chirp or tweet is about to end, the pulse width is reduced to zero over a short interval. This has been done to avoid any clicks from the piezo transducers, which would otherwise spoil the effect.

Circuit details

Fig.1 shows the circuit and it is quite simple, comprising two identical microcontrollers with both using the same software; one microcontroller acts as master and the other behaves as the slave. Power comes from a single 3V lithium button cell.

IC1 is the master microcontroller and has an LDR connected between its GP2 and GP5 inputs, to monitor the ambient light. To do this, the GP5 output, pin 5, goes low momentarily to connect the LDR and 470kΩ resistor in series between the +3V supply and 0V, via GP5.

When light is present, the LDR has a low resistance and so the GP2 input will be low; close to 0V. In darkness, the LDR's resistance is high and GP2 will be high; close to +3V. The voltage level at GP2 is duplicated at the GP4 output, which connects to the GP2 input of IC2. So when IC1 'sings', so does IC2.

But the GP4 output of IC1 is used more effectively than just following the LDR light level measurement. By taking advantage of the fact that the bird sound is not produced in darkness, the GP4 output of IC1 is also used to help IC2 resynchronise with IC1.

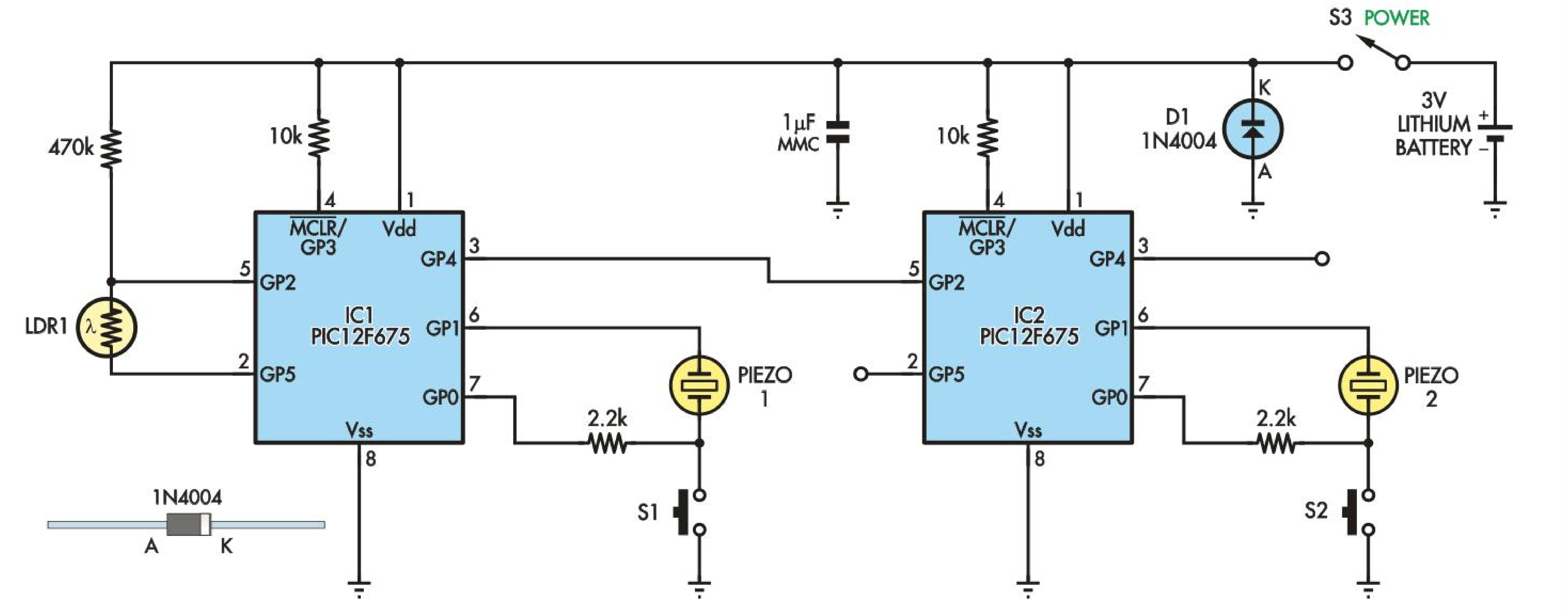


Fig.1: not much to it, is there! Basically, it's two microprocessors driving two piezo transducers. The bird songs can be altered by pressing S1 and/or S2.

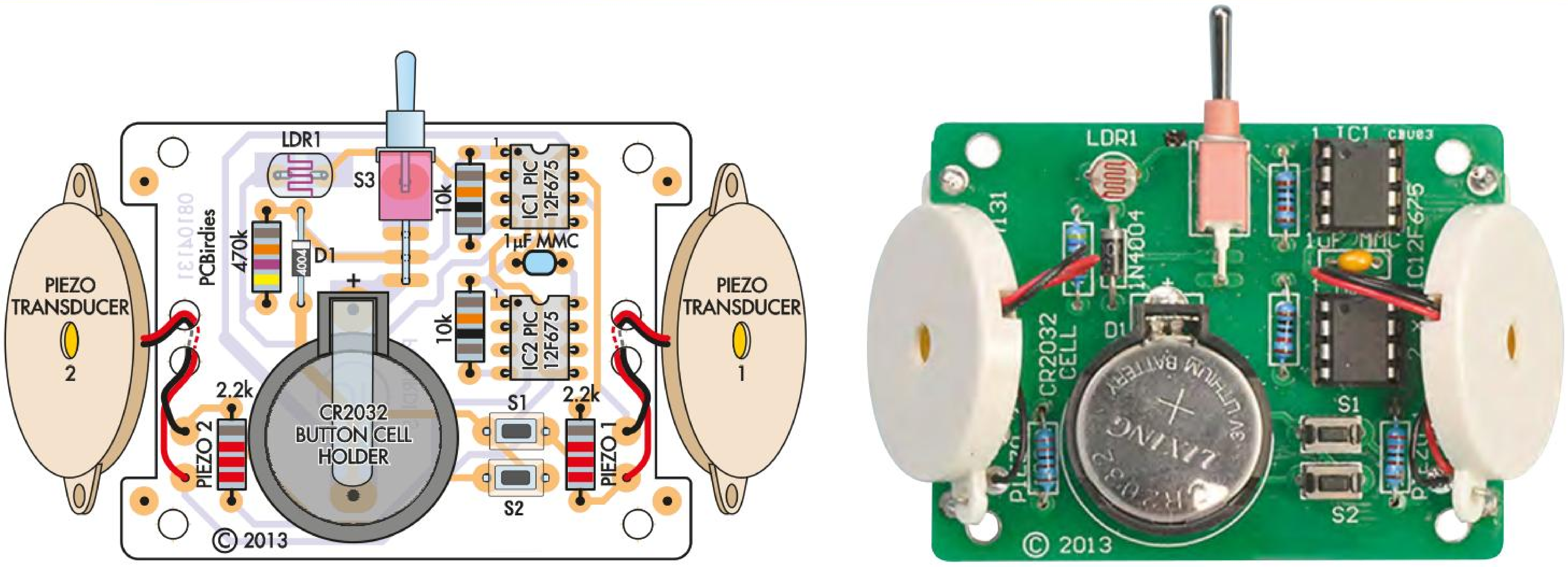


Fig.2: the component overlay for the PCB with a matching photo alongside. The piezo transducers are secured to the PCB, as described in the text, and the whole assembly pops into a UB5 box.

During longer phases of no output sound from IC1, the GP4 output is taken high. This sets IC2 to sense darkness and its timer, which determines the gaps between bird songs is reset.

As soon as IC1's gap timer ends, ready to play another bird song, it sets the GP4 output low and so IC2 is now also ready to begin singing. Random delay periods added between the GP4 output going low and the IC2 bird singing give the effect of the two birds singing together, sometimes but not always in synchronisation.

Each microcontroller drives its piezo transducer from the GP0 and GP1 outs, pins 6 and 7 with out-of-phase 3V signals; ie, when GP0 is high, GP1 is low and when GP0 is low, GP1 is high. This results in a 6V peak-to-peak drive signal to each piezo.

The 2.2kΩ resistor from the GP0 output is included for two reasons. One is to provide high frequency rolloff for the piezo signal, removing upper frequencies from the square wave drive. The rolloff is due to the 50nF capacitance of the piezo transducer combined with the series 2.2kΩ resistor; the result is a low-pass RC filter.

The 2.2kΩ resistor also prevents GP0 from being shorted to 0V when the switch (S1 for IC1 and S2 for IC2) is pressed. Normally, GP0 is set as an output, but at power up, GP0 is set as an input with an internal pullup holding this input high unless the switch is pressed.

Pressing the switch causes the microcontroller to change to the next bird sound available. This selection is stored in EEPROM so that the setting remains whether power is off or on.

Saving power

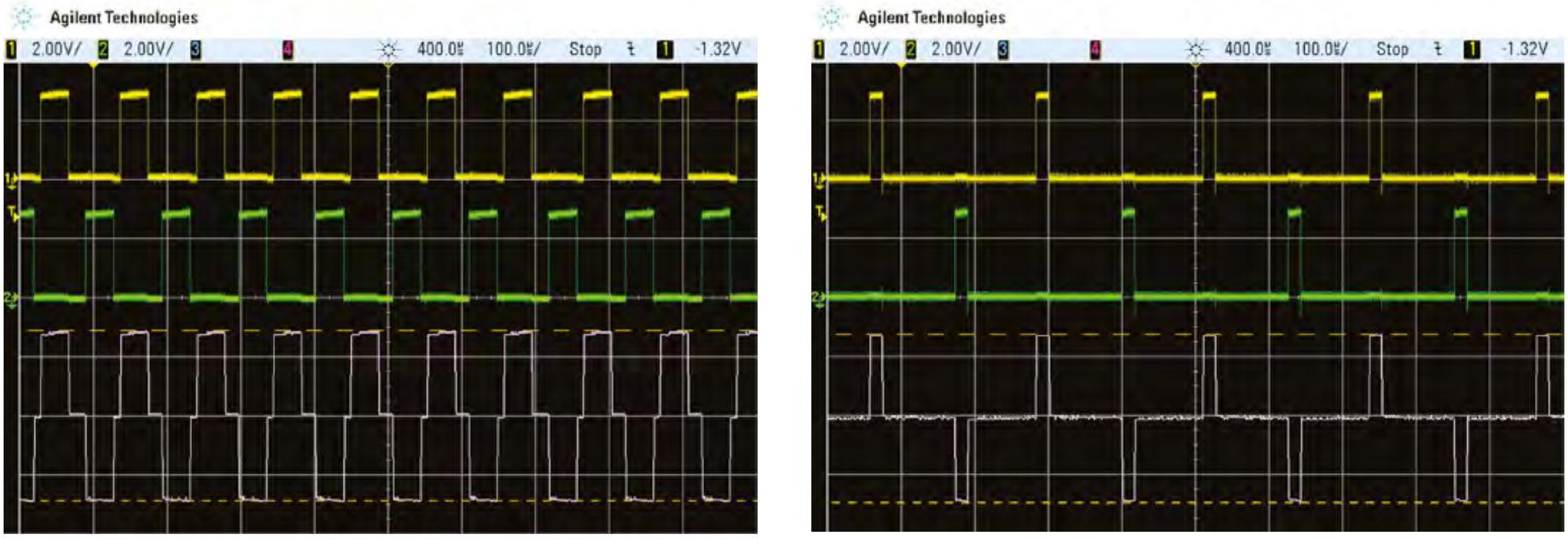
While PCBirdies is switched on, the current drain is 1.8µA per microcontroller during silence and 735µA per microcontroller while singing. Maximum current drain when both birds are singing is about 1.5mA. With the birds singing intermittently (as they do) we expect that you should get about 100 days of continuous use before the cell requires changing.

At around £1 to £2 per cell, that's a lot cheaper than bird seed!

Both microcontrollers use a watchdog timer which is repeatedly cleared during normal program running to prevent it from timing out and resetting the micro.

Typically, the watchdog timer will time out after 2.3s. During the gap period when there is no sound produced, the micro is in sleep mode and is woken up every 2.3s by the watchdog timer (perhaps its barking wakens the napping PCBirdies?)

The number of watchdog timer timeouts that occurs is counted to set the gap timer period. The gap timer is



These waveforms demonstrate how the microcontroller drives the piezoelectric transducer in push-pull. In the left screen shot, the yellow trace is the output at pin 6 while the green trace is the signal at pin 7. The mauve trace at bottom is the difference between the two signals which is applied to the transducer. The resulting waveform is equal to the sum of the two waveforms – in theory – but in practice it is less. The waveforms at right were taken for the same connections as in the scope screen at left, but the note is less than half the frequency and the duty cycle is also much reduced.

reset to zero with the LDR in darkness for IC1 and with GP2 high for IC2.

As already noted, power for the circuit comes from a 3V button lithium cell, type CR2032. Diode D1 is included to provide reverse polarity protection. Normally this should not happen, as the cell will only make an electrical connection to the cell holder if it is correctly inserted.

However, it is not unknown for some constructors to solder cell holders in the wrong way.

If that happens and a cell is inserted, the diode will conduct to protect the two microcontrollers but unless the cell is quickly removed (upon the awful realisation that it is in the wrong way) it will get hot and be quickly discharged.

The lithium cell is bypassed with a 1µF capacitor. Each micro has its MCLR connected to the +3V supply via a 10kΩ resistor. This provides a power-on reset each time power is first applied.

Construction

All components (including the battery and piezo transducers) for PCBirdies mount on a single PCB, available from the *EPE PCB Service,* coded 08104131 and measuring 62 × 48mm. It is housed in a translucent blue UB5 box that measures 83 × 54 × 31mm.

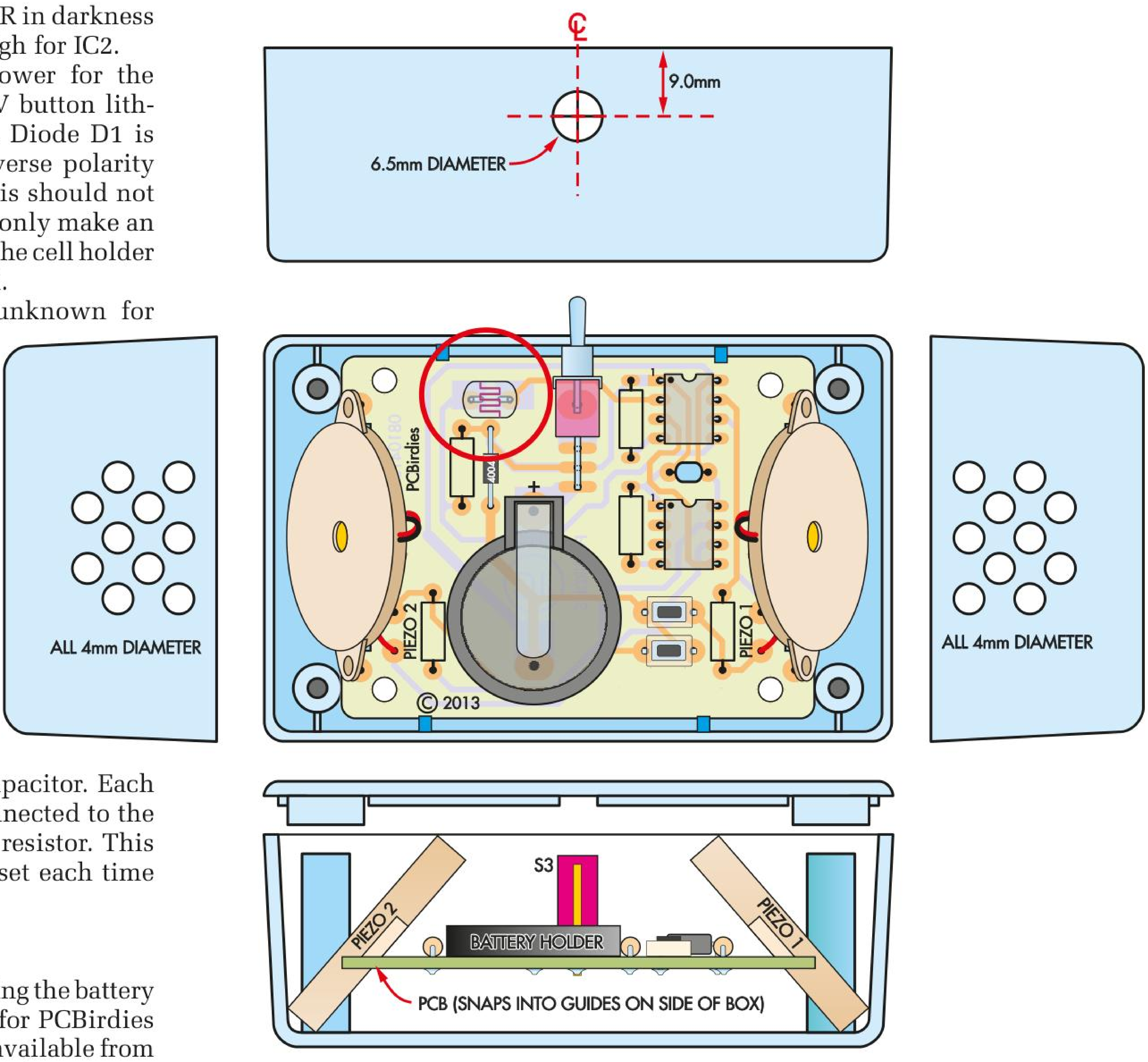
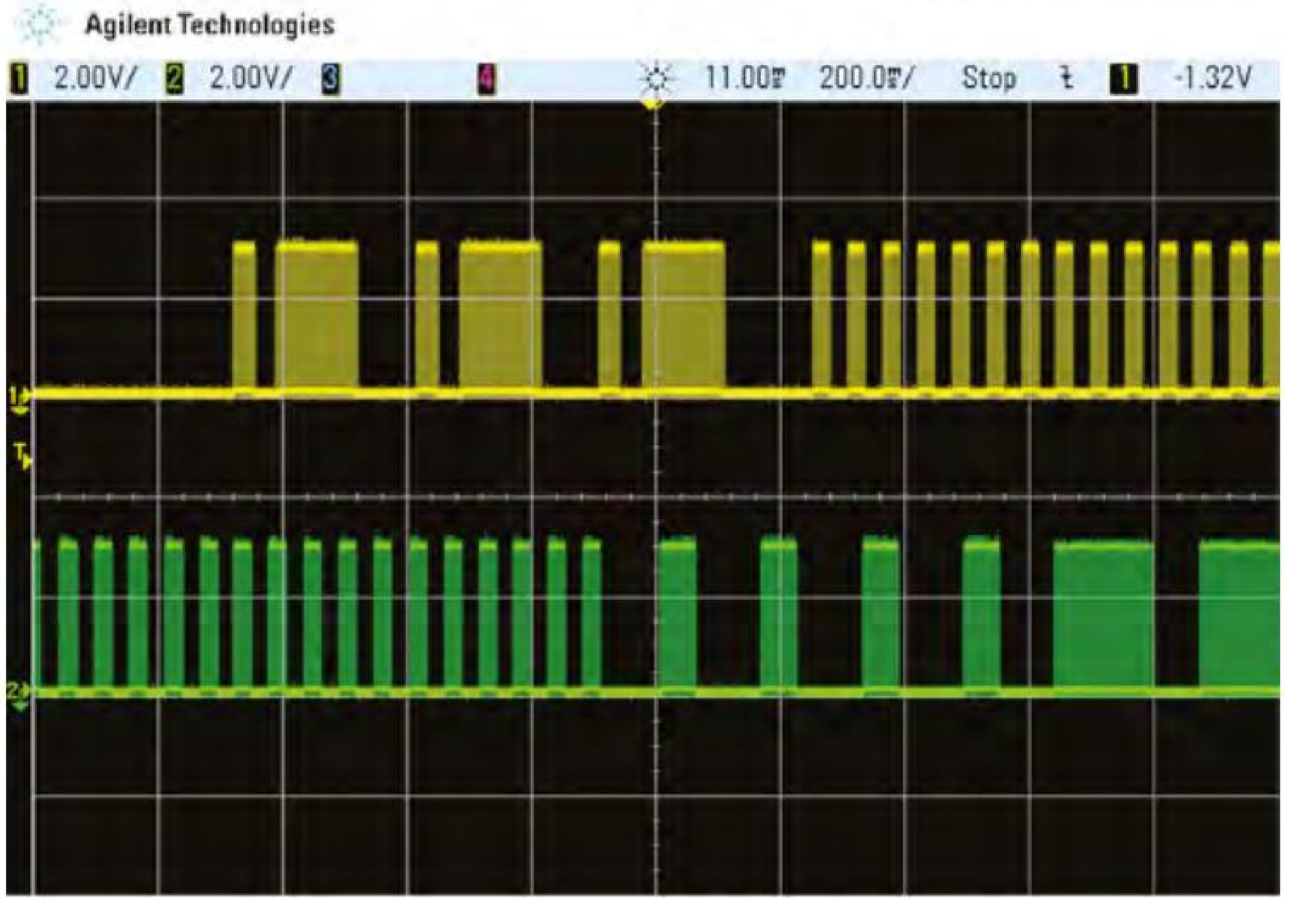
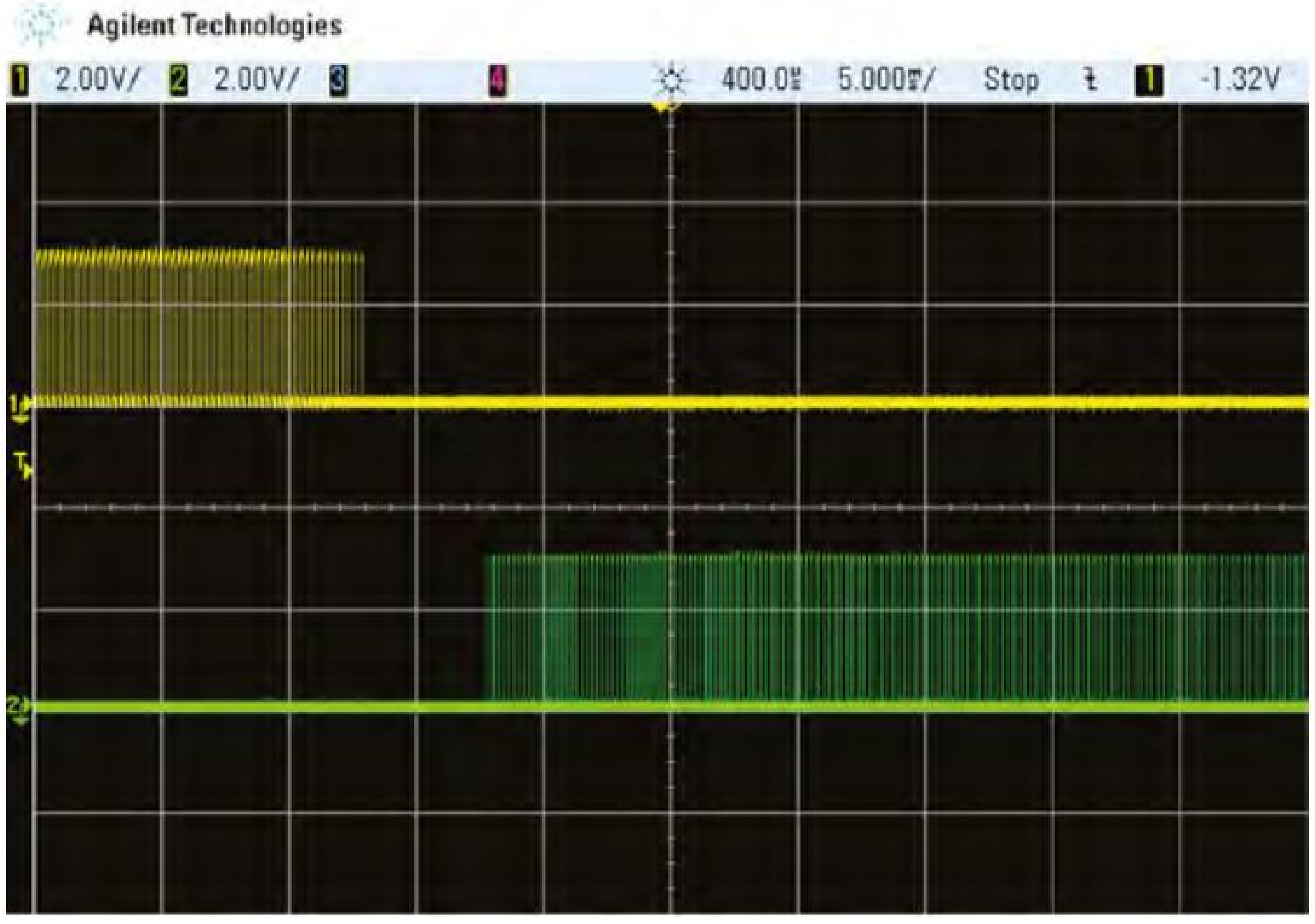


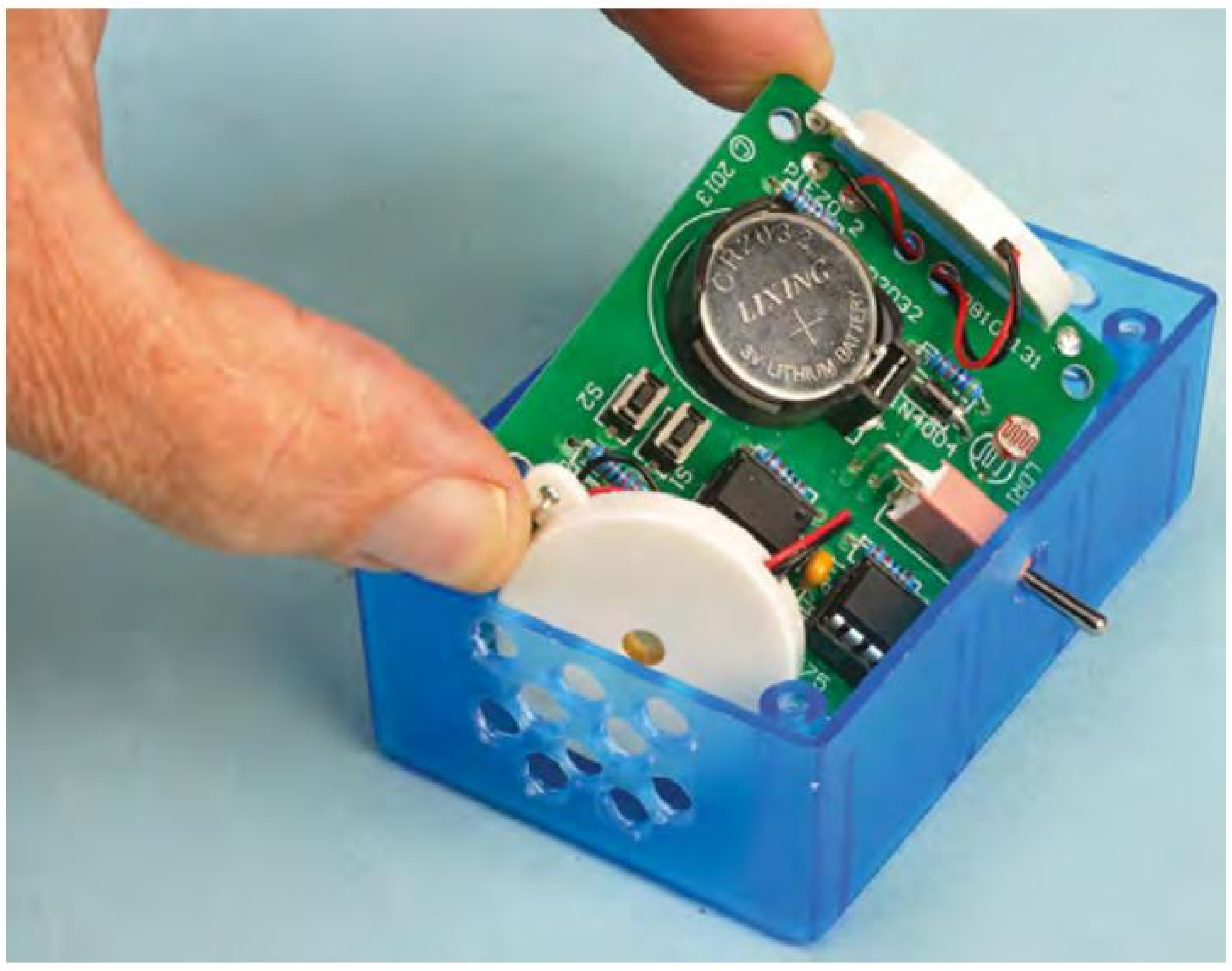
Fig.3: this diagram shows not only how it all goes together in the box, but also the positions for the switch hole (S3) and the sound holes in each end. You'll also need a hole in the case lid above the LDR (circled in red) if you don't use a translucent case.



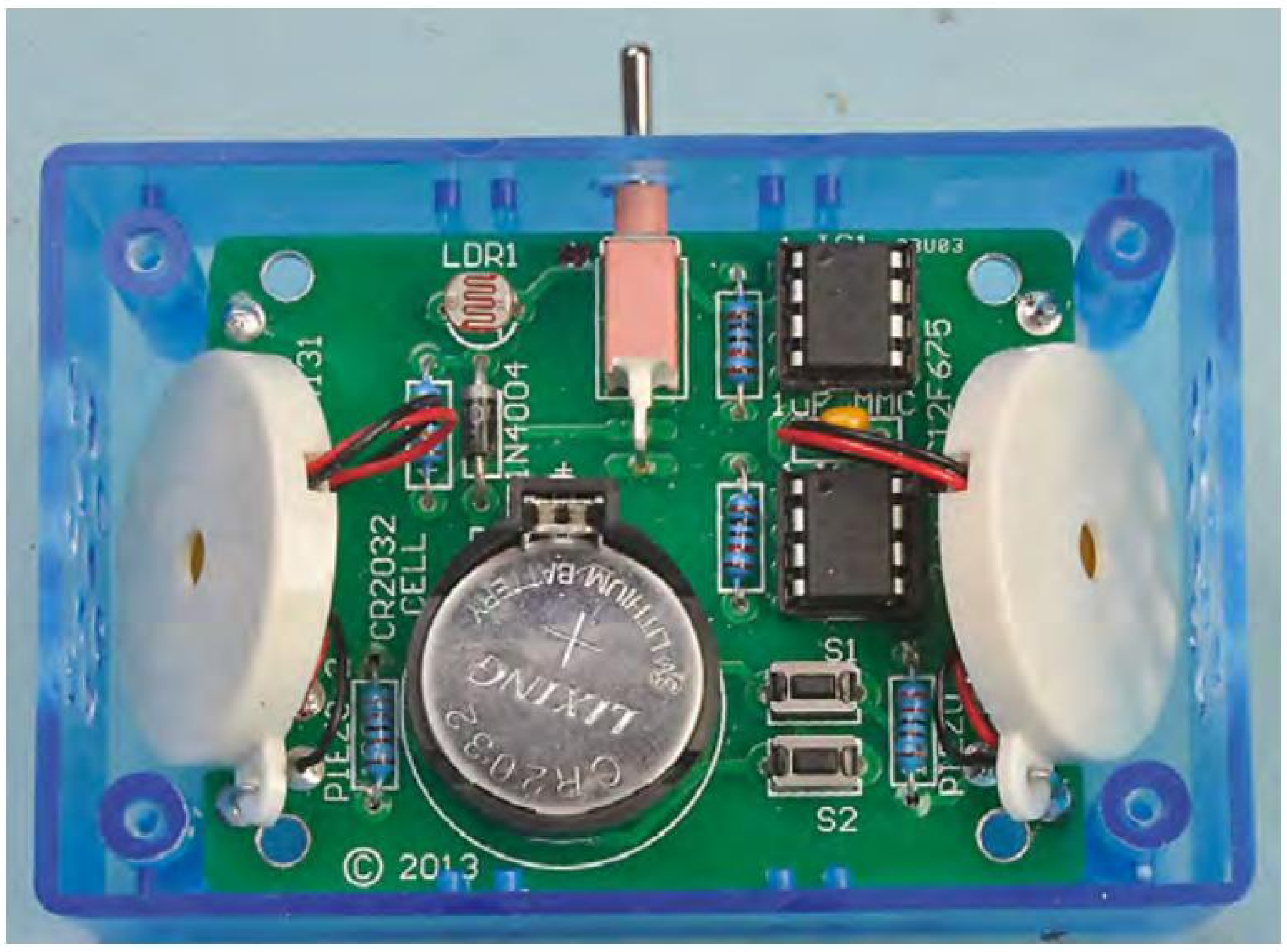
These waveforms show the songs being 'sung' simultaneously by the two microcontrollers, with the connections being at pin 7 in each case. Note that the songs are not synchronised even though they start out in sync at switch-on.



Taken at a faster sweep speed, these waveforms show how the beginning and the end of each pulse train has a much reduced duty cycle to avoid any tendency for the piezoelectric transducers to produce audible clicks, which would rather detract from the canary's song!



Once the PCB is built and tested it is inserted in the box. The idea is to 'slide' it in so that the power switch (S3) emerges through its hole in the box then the back of the board is pushed down so that it clicks into place in the mouldings on the case.



Here's what it looks like assembled inside the box. Everything is on the one PCB. If you have used anything but the translucent blue box, you'll need to drill a hole in the box lid so that the LDR (top, left of board) can 'see' daylight. Otherwise PCBirdies will never turn on!

Parts List – PCBirdies

1 PCB available from the *EPE PCB Service,* coded 08104131, 62 × 48mm
1 translucent blue UB5 box 83 × 54 × 31mm (see text)
1 PCB mount SPDT toggle switch (S1)
2 2-pin momentary pushbutton PCB mount switches
2 DIL8 IC sockets
1 PCB mount 20mm cell holder
1 CR2032 lithium cell
2 piezo transducers
1 LDR (LDR1)
Tinned copper wire

Semiconductors
2 PIC12F675-I/P microcontrollers programmed with 0810413A.hex (IC1,IC2)
1 1N4004 1A diode (D1)

Capacitors
1 1µF monotlithic multilayer ceramic (MMC)

Resistors (0.25W, 1% or 5%)
1 470kΩ (4-band code: yellow purple yellow brown)
2 10kΩ (4-band code: brown black orange brown)
2 2.2kΩ (4-band code: red red red brown)

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No screws or mounting posts are used – the completed PCB drops into the moulded rails on the side of the box, with the power switch emerging through the side.

A label measuring 78 x 49mm is fixed to the lid of the box.

Before installing the parts, check the PCB for any faults. Repair these as necessary. If you are building from a kit or using the PCB supplied from *EPE*, you will find that these PCBs are of excellent quality and so will not normally require any repairs.

Follow Fig.2 for the PCB component assembly.

Install the resistors and diode first. The resistors are colour coded with the resistance value. There are only three values of resistor; their colour codes are shown in the parts list. A digital multimeter should also be used to check the resistance values.

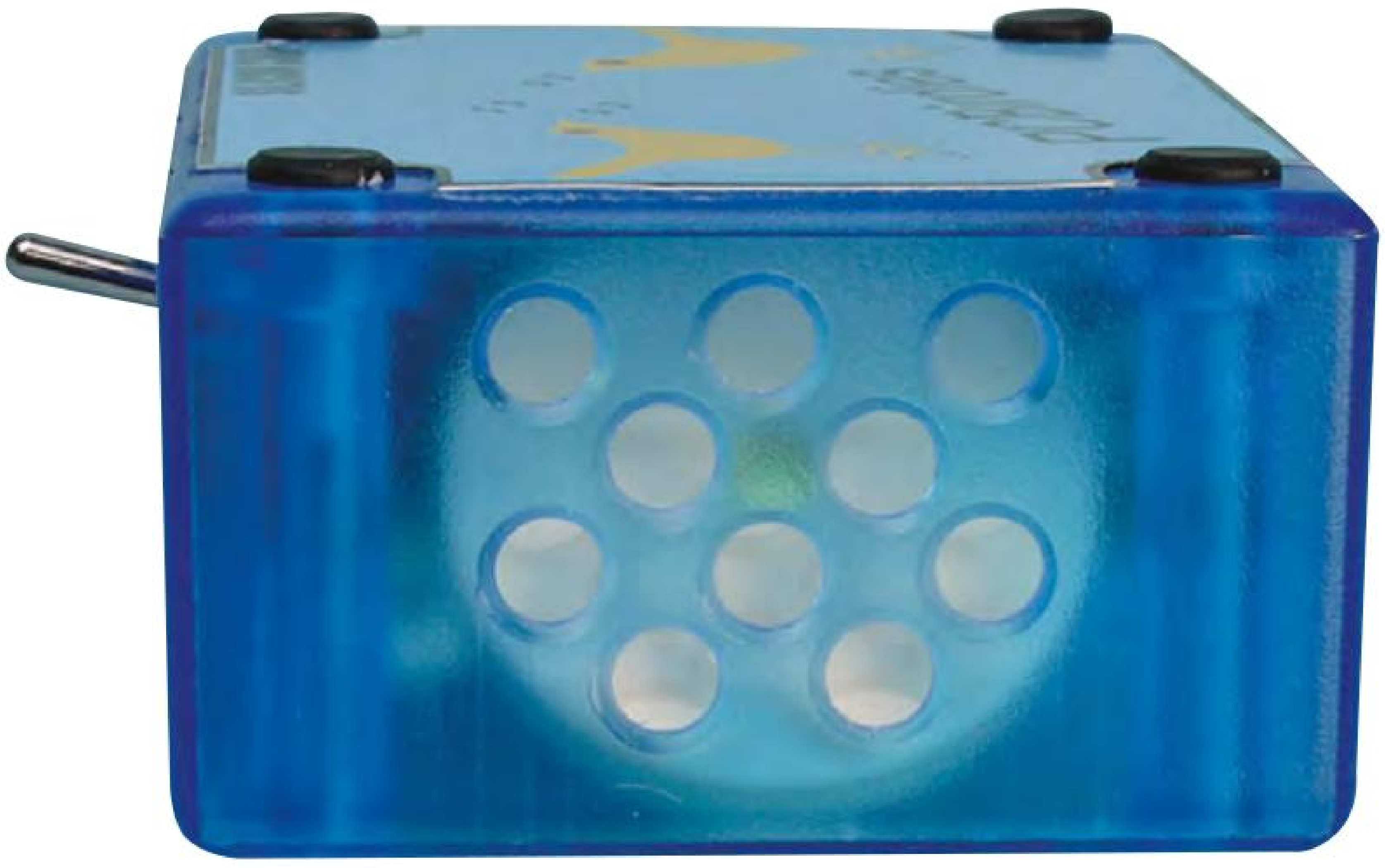
Make sure the diode is installed with the correct polarity with the striped end oriented as shown in the overlay diagram.

The capacitor can be installed next, along with the two push button switches and the IC sockets. Make sure the IC sockets are oriented correctly.

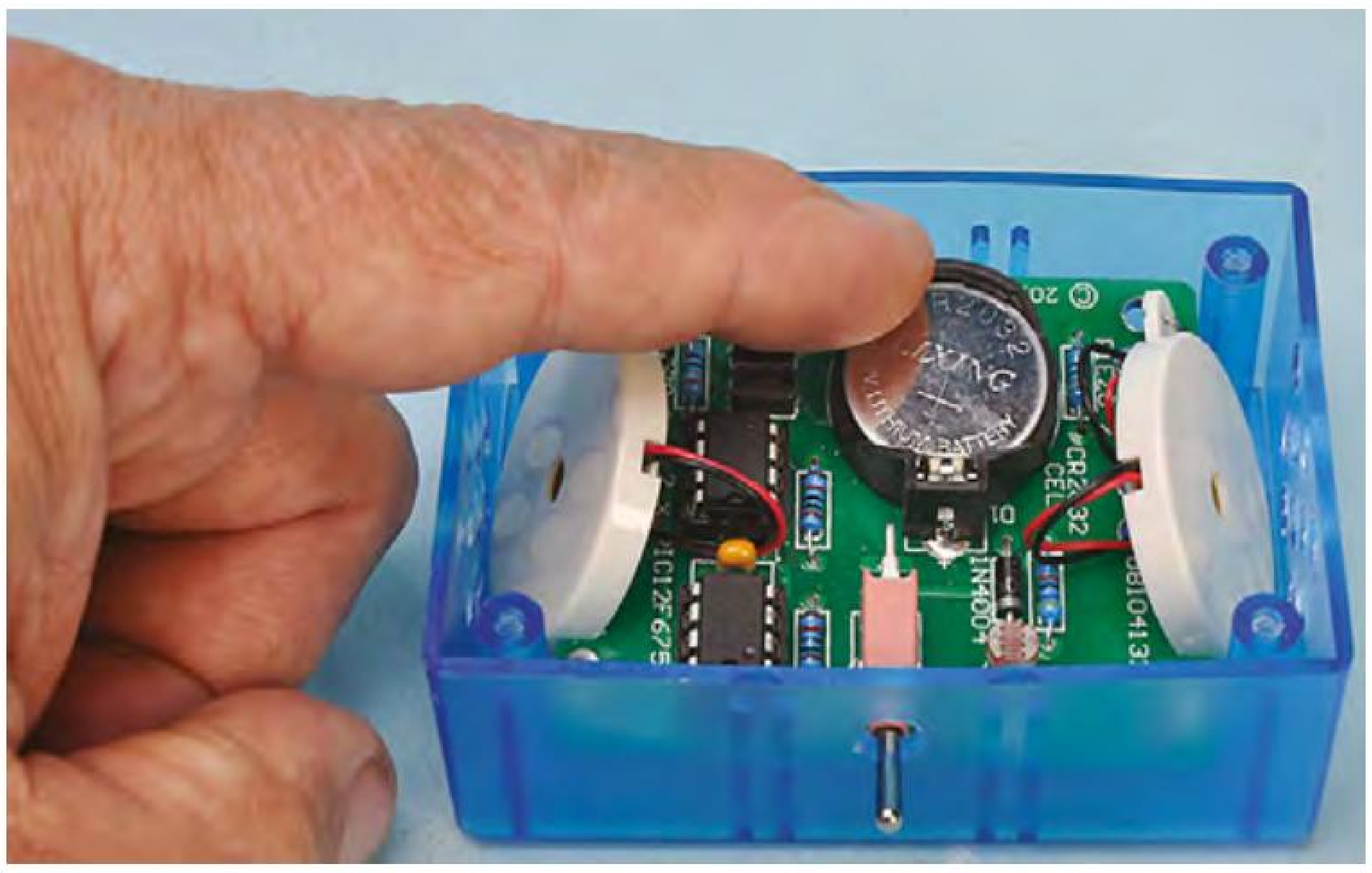
Power switch S3 is mounted hard-down on the PCB. Note that its main body terminal is soldered to the PCB before the remaining three switch pins are soldered.

The 20mm button cell holder can be installed next, taking care to orient this as shown.

If you are using a translucent case, then the LDR can be mounted at about 5mm above the PCB. That way the LDR will receive light through the box sides (even if a panel label is attached to the lid). If a grey or black case is used, then the LDR top face needs to be 14.5mm above the top of the PCB



Before placing the PCB in the box, you'll need to carefully drill sound holes in each end. If you don't do this there will be two very muffled canaries! The exact positions are not important, but you should aim to make the pattern symmetrical about the centre so it looks good!



If you don't get any sound from PCBirdies after final assembly (and it worked before you put the PCB in the box, make sure that the CR-2032 button cell is right down in its holder. Push it down so that it clicks into place to ensure reliable contact.

so that it can be inserted into a hole drilled in the lid of the case.

Insert the 3V cell into its holder and check that there is a 3V supply between pins 8 and 1 of each IC socket when switch S3 is turned on. If this is correct, turn the power switch off and mount the ICs.

The piezo transducers are mounted at about a 45° angle on the side of the PCB, sitting within the cut outs. Fig.3 shows the arrangement. We soldered the transducer wires directly into the signal output pads after first looping the wires through the two holes that provide for stress relief.

The piezo transducers have two flanges for mounting and we looped some tinned copper wire through the flanges and soldered these to the pads on the PCB. This keeps the transducers in position, with one flange on the top side of the PCB and the other flange on the bottom of the PCB.

The PCB is designed to clip into the integral side rails of the box. A 5mm hole is required in the side of the box for switch S3. The diagram shows where the hole should be.

If you must use a grey or black case, drill a suitable hole for the LDR in the lid, immediately above where the LDR is mounted.

An array of holes is also required in the ends of the box. Use the photos and diagrams for the positioning of the holes and drill these out to 4mm in diameter.

The front panel can be downloaded from the *EPE* website.

Print the label onto good quality thick paper – photo paper is ideal. It can be secured to the lid with a suitable glue or silicone. The hole for the LDR (required in a solid coloured box only) can be cut out with a sharp craft knife or leather punch.

Changing songs

When PCBirdies is first turned on, the bird sound produced by both IC1 and IC2 is the Fife canary. Changing the bird sound produced by IC1 is done by pressing S1 during power up. Similarly, changing the bird sound produced by IC2 is done by pressing S2 during power up. Power up involves switching off S3 for a few seconds, then switching it on again.

The pressed switch (S1 and/or S2) is released after 5s from power up. You can either press S1 on its own, S2 on its own or both switches during power up to change the song(s).

If just S1 is pressed and held during power up, then only the song produced by IC1 will change; similarly if just S2 is pressed, it's only the song produced by IC2 that changes. With both switches pressed, songs from both IC1 and IC2 will change.

There are four birdsong selections. The Fife canary birdsong is the first that is set in the program. The next selection is a different canary birdsong.

The third and fourth selections are medleys of the birdsongs. The third selection provides just a few of the more distinctive phrases used within the Fife and second canary songs. These are played at random.

The fourth selection provides a medley of both the full Fife canary repertoire, the full second canary song repertoire plus the phrases available from the third selection. These are all played at random.

You will return to the original Fife canary sound with the next selection accessed by S1 and S2 at power up.

If you want to have both IC1 and IC2 play the same repertoire, then press just one of the switches (S1 or S2) as many times as necessary during power up until that IC plays the same song as the other.

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USB Port Voltage Checker

Above: the unit can be used to check for voltage fluctuations when an external USB-powered unit is connected in-line with the *USB Port Voltage Checker.*

By NICHOLAS VINEN

If you carry valuable data around on a USB flash drive, it's not a good idea to plug it into other people's computers willy-nilly. They could have dead or faulty USB ports and an incorrectly wired USB port can destroy a flash drive – tragedy! Test it first with this handy *USB Port Voltage Checker*.

USB DEVICES ARE convenient for many reasons, and one of these is that you can walk up to just about any computer anywhere and plug a USB peripheral in. This is most useful for storage devices like flash drives and hard drives, but can apply to just about anything.

However, unless it's your computer and you know the ports are all working OK, there is the possibility that your treasured USB device will be damaged by a faulty port. This could happen for a few reasons. One is that front-panel USB ports are normally plugged into a USB pin header interface on the computer's motherboard via a multicore cable and these can be plugged in incorrectly, causing the port supply voltage to be reversed. That could easily damage a connected device. In fact, in this case, damage is likely.

There is also the possibility that the computer's power supply has a poorly regulated 5V rail, giving a port voltage that is too high, too low or fluctuating. This also applies for powered hubs and other devices where a failed plugpack could easily lead to trouble. Port voltages that are too high could also damage a connected device while voltages that are too low (permanently or only when current is being drawn) could lead to erratic device operation.

Well, that's enough about what could go wrong. This checker will show you when a USB port's voltage is in the correct range so you can plug in your flash drive or other device with confidence. You can even leave the unit connected and plug the device in piggy-back style, so you can continue to monitor the supply voltage during operation, to ensure it doesn't fluctuate too much.

The *USB Port Voltage Checker* is just 67 × 17 × 10mm – not much longer than flash drive. It's built on a small double-sided PCB measuring 44 × 17mm and is encapsulated in clear heatshrink tubing for protection. It uses a mixture of through-hole and surface-mount devices to keep it compact.

Circuit description

Fig.1 shows the full circuit. The USB plug (CON1) and socket (CON2) – both Type-A – are wired straight through, so the function of any USB device connected to CON2 is not affected. The D+ and D– signalling lines are run close together down the middle of the PCB so that the digital data signals are not affected, as well.

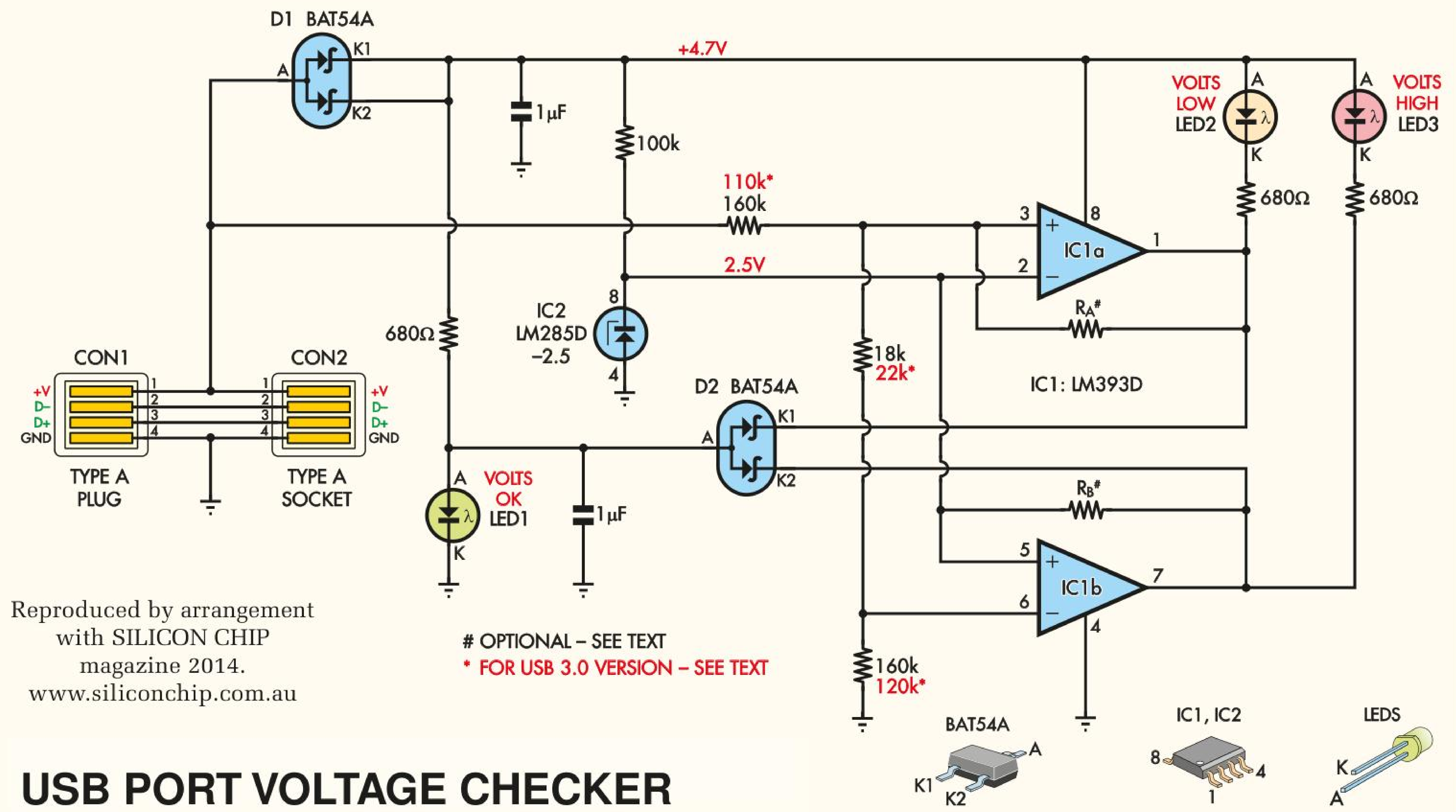
Schottky diode D1 rectifies the USB supply voltage so that if the polarity is reversed, nothing happens – no LEDs light, including the green one, so you know something is wrong with the port. This is a dual diode with a common anode connection, but we're using them both in parallel.

Why do this? Simply because we need one elsewhere and it's easier to use two identical parts than two different ones.

If all is OK, LED1 (green) is lit and this simply runs off the rectified voltage of around 4.7V with a 680Ω current-limiting resistor. Typical LED current is around:

(4.7V – 2V) ÷ 680Ω = 4mA.

IC2 is a 2.5V reference 'diode' which is actually an integrated circuit with two pins (well, it has eight but six are



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USB PORT VOLTAGE CHECKER

Fig.1: complete circuit of the *USB Port Voltage Checker.* It's based on dual comparator IC1 and voltage reference IC2. If the voltage is OK, green LED1 is lit while yellow LED2 and red LED3 indicate under-voltage and over-voltage respectively. If the supply polarity is reversed or voltage is very low, none of the LEDs light up.

unconnected). It is effectively a shunt regulator and it runs off the 4.7V supply via a 100kΩ resistor. That gives it a current of about:

(4.7V – 2.5V) ÷ 100kΩ = 22µA

with its recommended minimum being 10µA.

One half of dual low-power comparator IC1a compares this 2.5V reference to a divided-down version of the USB supply voltage. This is achieved with a resistive voltage divider comprising two 160kΩ resistors and an 18kΩ resistor. IC1a's inverting input (pin 2) is connected to the 2.5V reference, while the voltage at the non-inverting input is at (V+) × 0.527, where 0.527 is the divider ratio, calculated as:

(160kΩ + 18kΩ) ÷ (160kΩ x 2 + 18kΩ)

For USB 2.0, the minimum supply voltage is specified as 4.75V. If we plug this into the formula above, we get 4.75V × 0.527 = 2.5V, which is the same as the 2.5V reference it is being compared against. So when the USB supply drops below 4.75V, pin 3 of IC1a goes below 2.5V and IC1a's output switches low, turning on LED2, again with a current of about 4mA.

At the same time, IC1a also turns off green LED1 by pulling its anode low through half of dual-Schottky diode D2. Thus, if the USB voltage is too low, the yellow LED turns on and the green LED turns off.

A 1µF capacitor across LED1 ensures that it is switched off for a minimum period (a few milliseconds) even if there is a brief drop in the USB voltage. That won't be noticeable in isolation, but if the USB voltage is dropping below 4.75V often enough, it means that LED1 will either dim or go off entirely.

Note that the PCB has provision for an SMD resistor labelled R_A to add hysteresis for comparator IC1a. However, we don't think it's necessary.

Over-voltage checking

The circuit to detect over-voltage is similar. In this case, comparator IC1b is used, as is the same 2.5V reference voltage from IC2. This time, however, the division ratio is different, as IC1b's inverting input is connected to the other end of the 18kΩ resistor. That means the formula to calculate the comparator threshold is (V+) × 0.473, which means the upper threshold is a little above 5.25V. Again, we can check this by doing the calculation:

5.25V × 0.473 = 2.48V.

So red LED3 will turn on if the supply voltage goes much over 5.25V. As with IC1a, IC1b's output going low also turns off LED1, via the other half of dual-diode D2.

Pads for a hysteresis resistor (R_B) are supplied, but as before, we don't think it's necessary. If R_B is fitted, its value will need to be chosen carefully – see below.

USB 3.0 support

The 4.75-5.25V (ie, 5V±5%) USB supply range is from the USB 2.0 specification. The newer USB 3.0 specification allows for more current to be drawn by USB devices and as such, also allows a wider variation in supply voltage, ie, 4.45-5.25V. While we don't think it will happen very often, this means that with a USB 3.0 port, the under-voltage indication (ie, yellow LED lit) could occur while operating within specifications.

If you want to accommodate this, you can do so by changing the divider resistor values, ie, use the values shown in red on the circuit diagram. The divider ratios then become 0.563 and 0.476, giving an upper threshold of 2.5V ÷ 0.476 = 5.25V and a lower threshold of 4.44V.

Accuracy

The 2.5V version of the LM285 voltage reference has a tolerance of ±1.5%

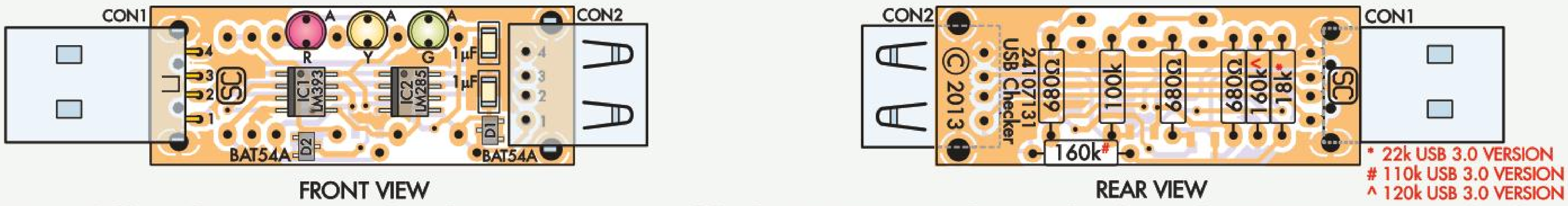
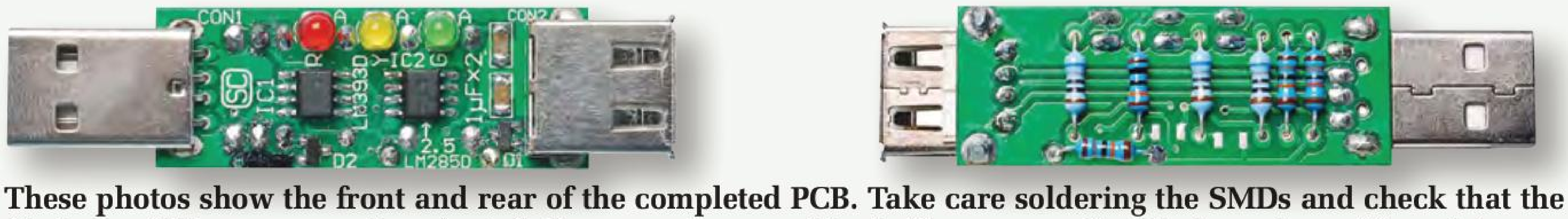


Fig.2: follow these PCB overlay diagrams to assemble the *USB Port Voltage Checker*. The SMD parts (ICs, diodes and capacitors) all go on the top side, along with the LEDs and connectors, while the resistors are all fitted on the bottom side. The two empty pads on the bottom are for optional hysteresis setting resistors.



These photos show the front and rear of the completed PCB. Take care soldering the SMDs and check that the diodes and ICs are correctly oriented. You can remove solder bridges across the IC pins using solder wick.

which translates into an error of about ±0.08V referenced to the USB supply voltage. Taking into account resistor tolerances and variations in the forward voltage of D1, the maximum error could be more than that. There is also a roughly +5-10mV error due to the input bias current of IC1a and IC2a flowing through the divider network.

An error of ±0.1V would be fairly significant compared to the ±0.25V specification for the USB 2.0 supply, but this is a worst-case figure, and without taking any special care, our prototype's thresholds measured very close to what we calculated above. You would be unlucky to build one of these and find it had more than ±0.05V error.

Our (randomly chosen) LM285 measured 2.4946V, which is an error of just –0.22%. One easy way to check the accuracy of your voltage reference IC is to use a DMM to measure the voltage across its lower-left and upper-right pins while power is applied. If your reading is much lower than ours, try reducing the value of the 100kΩ resistor feeding it (eg, to 10kΩ) as a higher operating current should (slightly) increase the reference voltage.

Construction

Fig.2 shows the assembly details.Begin the construction by fitting the SMD components to the PCB, which is available from the *EPE PCB Service*, coded 24107131. Install the two ICs first. Figure out which is which and then locate pin 1, which is normally indicated by a divot or dot in the corner of the plastic package. It could also be indicated by a stripe along the top of the IC (between pins 1 and 8) or by a bevelled edge which will be on the pin 1 side.

Put a little solder on one of the IC pads then place the chip in the correct position, with pin 1 at upper-left. While heating that solder, slide it into position. You can re-heat the solder and adjust it if necessary, then solder the rest of the pins. Finally, add a little solder to the first pin you soldered, to refresh it.

If any pins are bridged, you can clear them using solder wick, although often all that's required is to slide the soldering iron tip between the pins and then back again (assuming it's fine enough).

Now fit the two SMD dual diodes. Their orientation should be obvious as long as they are not upside-down, ie, solder them with their leads touching the PCB. Then mount the two ceramic capacitors, again using a similar technique but make sure you wait a bit between soldering one pad and the other to ensure the first joint has solidified before making the second.

The through-hole components can then go in. The resistors go on the other side to the SMDs (check each one with a DMM before fitting it). The three LEDs go on the same side as the SMDs, with their anodes to the edge of the board.

Finish up by fitting the two USB connectors – the socket (CON2) is optional but recommended. Ensure that their mounting tabs are fully pushed into the corresponding holes on the PCB before soldering them and then finally the signal pins.

You can test it by simply plugging it into a known-good USB port; the green LED should light while the others should remain off. If you have a variable voltage DC supply, you can wire it up across the USB pins (using a spare plug perhaps) and then vary it between 4.5V and 5.5V to check that the yellow and red LEDs come on at the correct voltages.

Once you're satisfied, slide some clear heatshrink tubing over the unit and shrink it down.

Hysteresis

As noted above, you probably don't need to add resistors for comparator hysteresis. The advantage of hysteresis is that a brief excursion beyond one of the thresholds is more likely to cause

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	2	160kΩ	brown blue yellow brown	brown blue black orange brown
☐	1	120kΩ	brown red yellow brown	brown red black orange brown
☐	1	110kΩ	brown brown yellow brown	brown brown black orange brown
☐	1	100kΩ	brown black yellow brown	brown black black orange brown
☐	1	22kΩ	red red orange brown	red red black red brown
☐	1	18kΩ	brown grey orange brown	brown grey black red brown
☐	3	680Ω	blue grey brown brown	blue grey black black brown

USB port polarity: a simple approach

This project was inspired by reader Bruce Pierson, who sent in details of a simple design to check USB port supply polarity. As you can see, his design consists of just a USB plug (surface-mounting type), an LED and a resistor, all soldered to some Veroboard and housed in the plastic case from a defunct flash drive.

If all you want to do is check the supply polarity then this is not a bad idea and it's certainly much less complicated than our approach. But obviously, it won't give you much information as to whether the bus voltage is too low or too high unless it is grossly so and you will have no way of monitoring the bus voltage on that port while another device is connected.

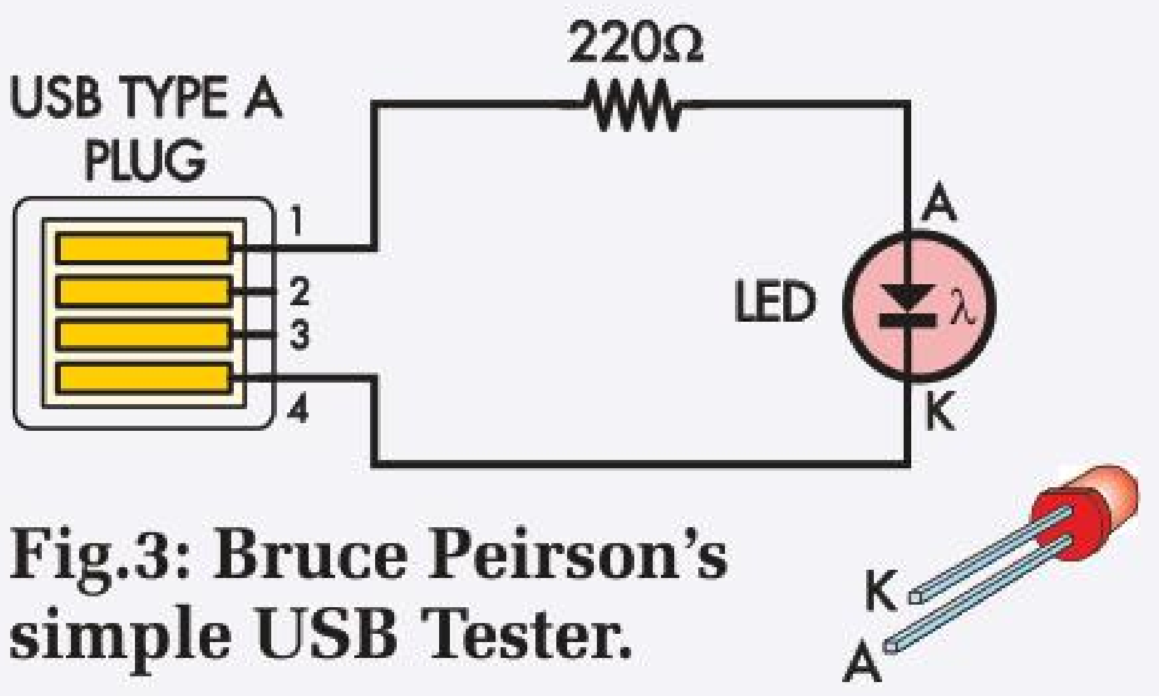


Fig.3: Bruce Peirson's simple USB Tester.

the LED to come on and stay on rather than flicker so briefly that you may not notice it. In practice, what happens as the bus voltage crosses the threshold is that one LED appears to fade in while the other fades out, due to rapid switching between them.

If you decide to add hysteresis, choosing a value for R_A is fairly simple. With R_A = 10MΩ, once the supply voltage drops below the lower voltage of 4.75V, this threshold is changed to about 4.77V by the fact that R_A is effectively in parallel with the lower part of the voltage divider. In other words, it will give about 20mV of hysteresis.

A lower value resistor will give proportionally more hysteresis. Much more than 100mV of hysteresis is probably not desirable, giving a minimum value of 2.2MΩ or so. Note that fitting R_A will also shift the lower threshold needed to turn on LED2 as well, but only very slightly.

Choosing a value for R_B is more tricky, because when IC1b's output is low, it is effectively in parallel with IC2 and we must also consider that some or all of IC1b's input bias current will flow through it. A sensible value would be around 91kΩ. This forms a divider with the 100kΩ resistor supplying current to IC2 such that the reference voltage should be pulled down to about 2.35V when IC1b's output is low, providing around 0.3V of hysteresis for the lower supply threshold.

We haven't tried this though and obviously, if you change the 100kΩ resistor value you will need to scale R_B similarly.

The pads for R_A and R_B are designed to accept metric 3216 or imperial 1206-sized SMD chip resistors.

Using it

Simply plug it into a USB port. If it shows a green light, it's OK. You can then either unplug the checker and connect your USB device or you can simply leave it in and plug your device into its socket. It should not affect operation.

If no LEDs light, then either the port is dead or its supply polarity is reversed. Either way, we don't recommend plugging anything else into that port before you check it out. Similarly, if you get a red LED, be careful – the voltage may be just a touch high. Most USB devices won't be damaged but you will need to measure it to be sure.

Parts List

1 double-sided PCB with plated-through holes, available from the *EPE PCB Service*, code 24107131, 44 × 17mm
1 PCB-mount USB type A plug (CON1) (element14 2067044 or 1696544)
1 PCB-mount USB type A socket (CON2) (element14 1696534) – optional, see text
1 60mm length 16mm-diameter clear heatshrink tubing

Semiconductors
1 LM393D dual low-power comparator (IC1) [SOIC-8] (element14 4380563 or 2294229)
1 LM285D-2.5 micropower voltage reference (IC2) [SOIC-8] (element14 8389195)
2 BAT54A dual common-anode Schottky diodes (D1-D2) [SOT-23] (element14 1081191)
1 green 3mm LED (LED1)
1 yellow 3mm LED (LED2)
1 red 3mm LED (LED3)

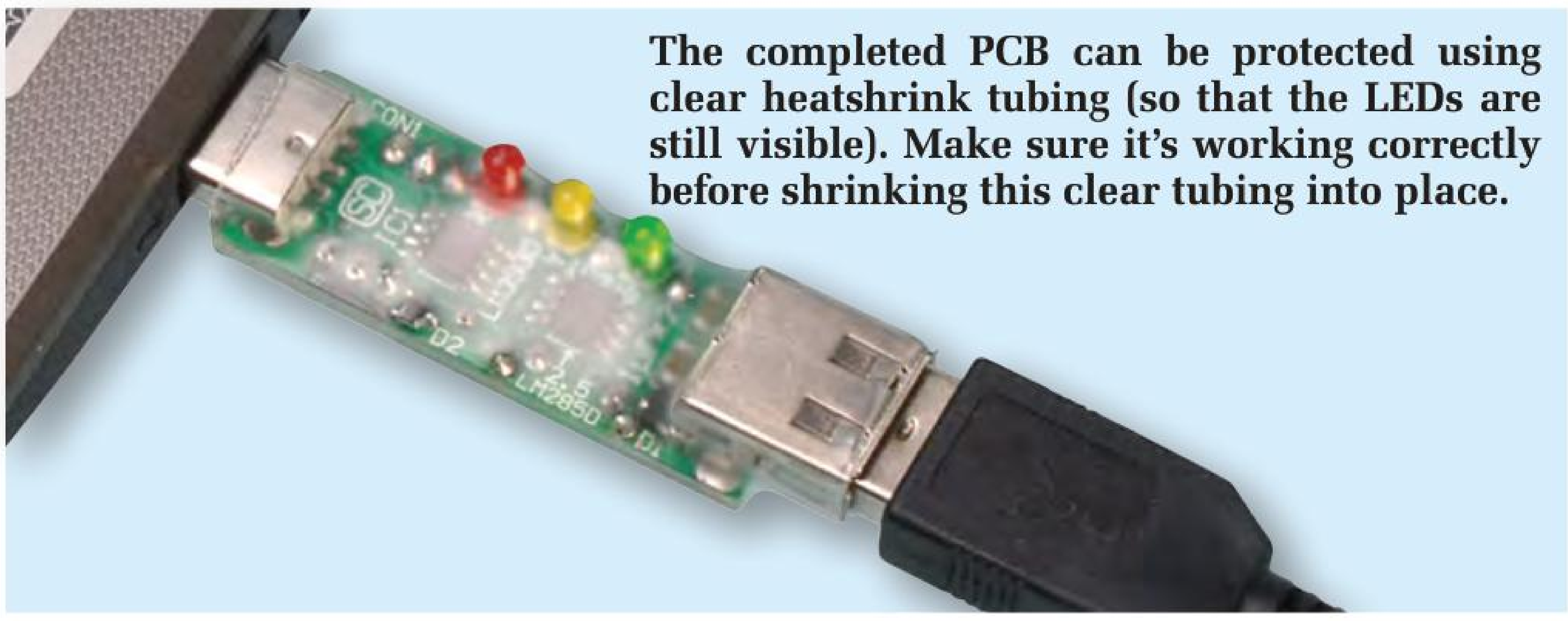
Capacitors
2 1µF 16V SMD ceramic [3216/1206] (element14 1683655)

Resistors (0.25W, 1%)
2 160kΩ**
1 120kΩ*
1 110kΩ*
1 100kΩ
1 22kΩ*
1 18kΩ**
3 680Ω
* USB 3.0-compatible version
** USB 2.0-compatible version

Note: a kit for this project is available from Jaycar, Cat. KC-5522.

If the yellow LED is lit, the low voltage is unlikely to damage anything, but your USB device may not get enough power to operate properly. Note, if the bus voltage is very low, it's possible the red LED could also light (dimly).

Some chargers which use USB ports can put out as much as 6V. This is most common with high-current chargers in the 2-3A range, such as for tablet computers. We believe this is an attempt to get the maximum current through the USB cable. While most devices will tolerate 6V, some could overheat and in theory damage could occur, so take care plugging anything not designed for these chargers into them.



The completed PCB can be protected using clear heatshrink tubing (so that the LEDs are still visible). Make sure it's working correctly before shrinking this clear tubing into place.

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0V
+5V
14108131
iPOD Charger
3
2
1

By JOHN CLARKE

This simple iPod charger adaptor uses just a few parts and mates with a standard 5V switchmode plugpack or a standard USB supply/charger. If you already have a 5V plugpack, it will cost you less than a proprietary charger and is easy to build.

WHILE iPODs can be charged via a computer USB port, this is not always convenient and a separate charger is more useful. That way, you can charge from the 230VAC mains or from a USB power outlet that plugs into the lighter socket of a car. However, iPod chargers from Apple and other suppliers can be expensive, while low-cost chargers bought online might not work with some iPod models.

Generic USB plugpack supplies and chargers are much cheaper – but they won't work with iPods. Instead, you will be left with a 'charging is not supported with this accessory' warning. However, with just a few minor additions, you can get a generic 5V supply/charger to work.

There have been iPod Charger designs that comprised a 5V switchmode regulator fed from a 9-15V DC plugpack, with an output via a USB socket. These worked with the first generation (1G) iPod nano. Naturally, later designs enabled chargers to work with subsequent iPod releases from Apple.

Essentially, four resistors have to be added across the 5V supply to provide a DC voltage at the D+ and D– (data lines) of the USB socket. These are required for iPods to recognise the charger as valid before charging occurs.

Nowadays, an iPod charger can be much simplified. We can just use a cheap 5V regulated plugpack or USB supply or charger directly. Add a USB socket, and some resistors to set the voltage at the D+ and D– inputs on the USB socket and that's all that is required.

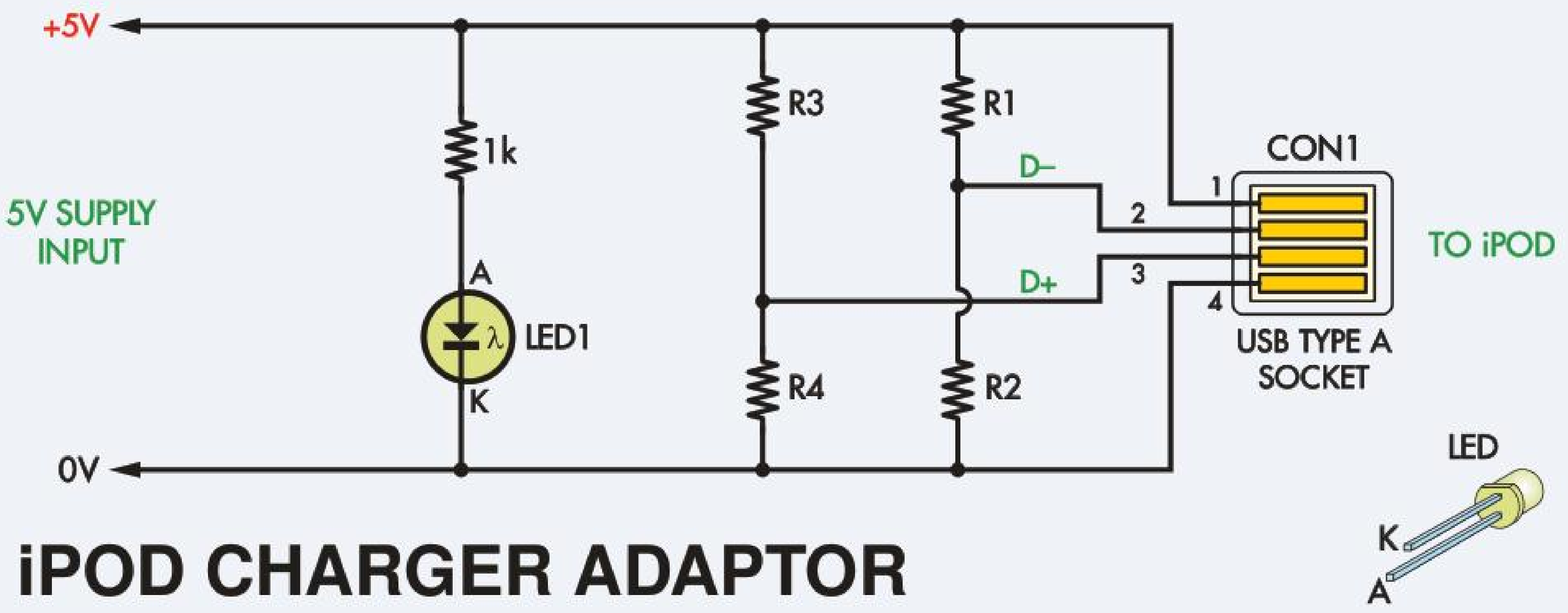
Circuit details

Fig.1 shows the circuit. The 5V supply connects to the 5V and 0V terminals, ie, pins 1 and 4 respectively of the type 'A' USB socket. Resistors R1 and R2 form a voltage divider network across the 5V supply for the D– (Data minus) input, while R3 and R4 set the voltage for the D+ input. A 1kΩ resistor provides current limiting for the power LED (LED1). We used a blue LED, but any colour could be used including red, green, yellow, orange, white and aqua.

Construction

The parts are assembled onto a PCB available from the *EPE PCB Service,* coded 14108131 measuring 18 × 60mm. Fig.2 shows the layout details. Install the resistors first, checking the values as you go with a digital multimeter. Table 1 shows the values for resistors R1-R4 to suit different iPod models (and for the Samsung Galaxy Tab2), while Table 2 also shows the resistor colour codes.

It's just a matter of selecting the resistors to suit your particular device. We recommend that these resistors are only tack-soldered in first and the charger adaptor tested before fully soldering the resistors directly onto the PCB. Make sure that the supply you will be using can deliver the necessary current if you want to charge at 500mA or 1A.



iPOD CHARGER ADAPTOR

Fig.1: the circuit uses just a few resistors, a power indicator LED and a type 'A' USB socket. Power comes from a regulated 5V plugpack supply.

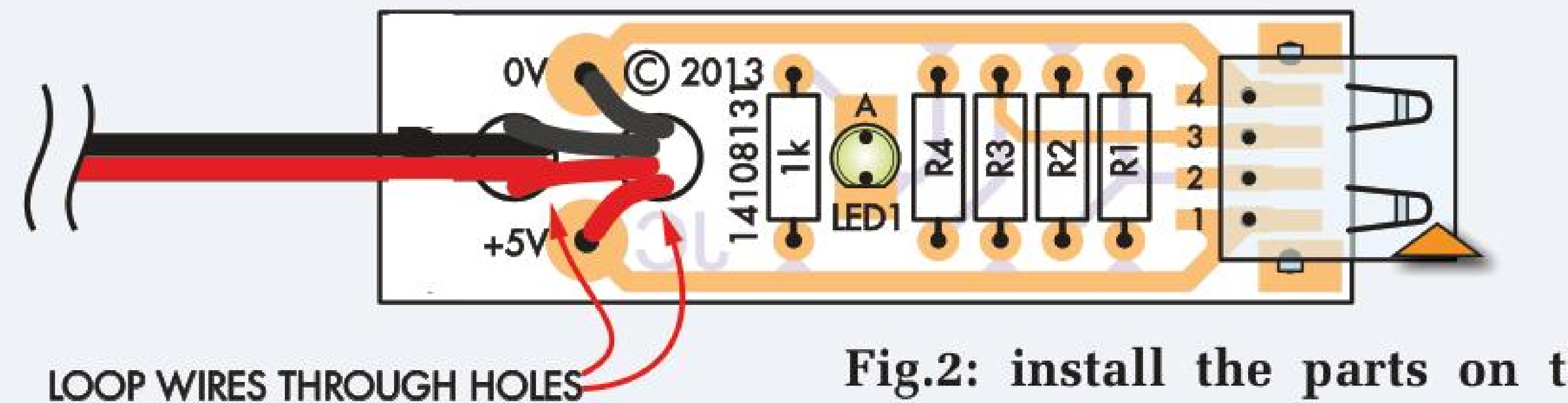
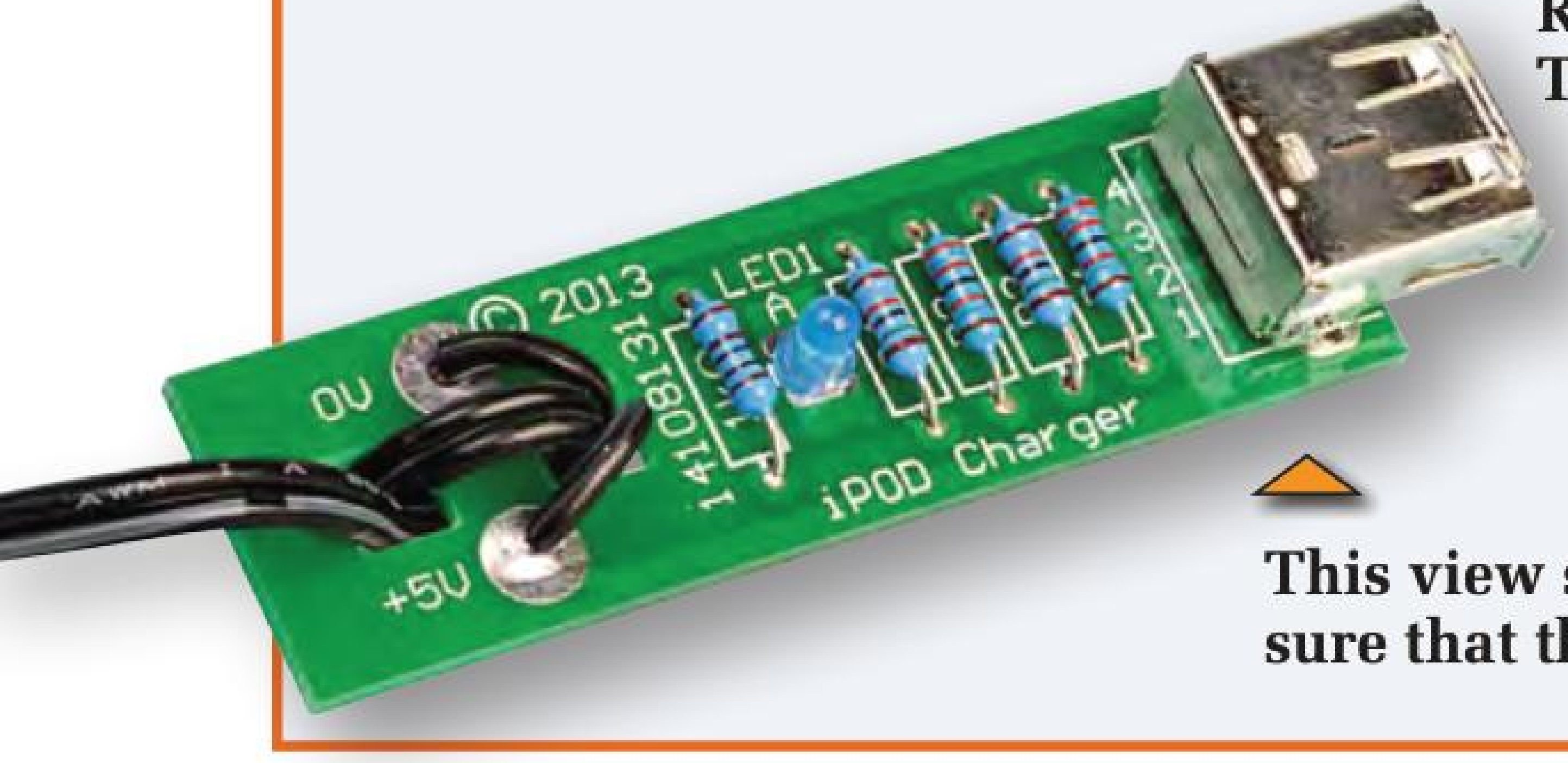


Fig.2: install the parts on the PCB as shown in this diagram. Resistors R1-R4 are selected from Table 1 to suit the iPod model.



This view shows the completed PCB. Make sure that the LED is oriented correctly.

Parts List

- 1 PCB, available from the *EPE PCB Service* code 14108131, 18 × 60mm
- 1 5V 1A regulated plugpack OR
- 1 5V USB charger/supply and 1 USB 'A' line plug with a length of light-duty figure-8 wire OR
- 1 USB type 'A' plug and cable cut from a USB extension lead
- 1 PCB-mount USB type 'A' socket
- 1 75mm-length of clear 20mm diameter heatshrink tubing
- 1 3mm LED (any colour) (LED1)

Resistors (0.25W, 1%)

1 33kΩ
2 22kΩ
1 18kΩ
2 15kΩ
1 10kΩ
1 1kΩ

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The LED indicator is mounted directly on the PCB. Make sure it is oriented correctly with the anode (longer lead) inserted as shown on Fig.2. Solder its leads quickly to avoid heat damage.

The USB socket goes in last. It must be pushed right down onto the PCB before its outer mounting lugs are soldered. Its four pin connections can then be soldered.

The 5V power input can come from either a 5VDC plugpack or a USB supply (eg, a plugpack with a USB socket). As shown, the leads from a plugpack are directly soldered to the 5V and 0V terminals after the wires have been looped through two holes at one end of the PCB. This is done to provide stress relief for the connections.

Make sure the that the plugpack's leads are connected to the correct pads. If in doubt, check the voltage between its leads before making the connections.

If you intend using a USB supply, a cable fitted with a USB type 'A' plug at one end will have to be wired to the PCB. Fig.3 shows the details.

Note that we do not mean using a USB supply on a computer here, since all iPods can be charged from a computer USB port. However, USB ports on a charger are different in that they supply power via pins 1 and 4 of the USB socket, but there is no communication via the D+ and D– lines.

Making the USB cable

You can obtain a suitable cable by cutting off the socket from a USB extension cable (ie, the socket at the opposite end of the cable to the type 'A' plug). That done, strip back the insulation and connect the red wire to the +5V input on the PCB and the black wire to the 0V input. The unused

Table 1: Selecting resistors R1-R4

iPod touch/iPhone/ iPod NANO 2G	iPod touch/iPhone (if product allows for 1A charge)	iPod Mini, nano 2G, Shuffle 2G	iPod Mini	iPod nano 1G and iPod Video 5G	Samsung Galaxy Tablet
D– @ 2V D+ @ 2V 500mA charge	D– @ 2.7V, D+ @ 2V 1A charge	D– @>3V, D+@>3V 250mA charge (Mini and nano), 100mA (Shuffle)	D– @ 0V, D+ @ >3V 100mA charge	D– @ >3V, D+ @ 0V 500mA charge	D– @ 1.2V D+ @ 1.2V charge unknown or ≤1A
R1 = 22kΩ	R1 = 18kΩ	R1 = 22kΩ	R1 = Omit	R1 = 22kΩ	R1 = 33kΩ
R2 = 15kΩ	R2 = 22kΩ	R2 = Omit	R2 = 22kΩ	R2 = Omit	R2 = 10kΩ
R3 = 22kΩ	R3 = 22kΩ	R3 = 22kΩ	R3 = 22kΩ	R3 = Omit	R3 = 33kΩ
R4 = 15kΩ	R4 = 15kΩ	R4 = Omit	R4 = Omit	R4 = 22kΩ	R4 = 10kΩ

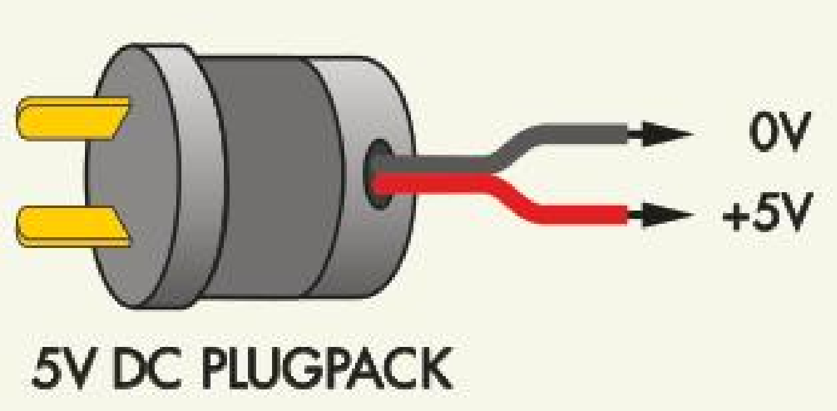
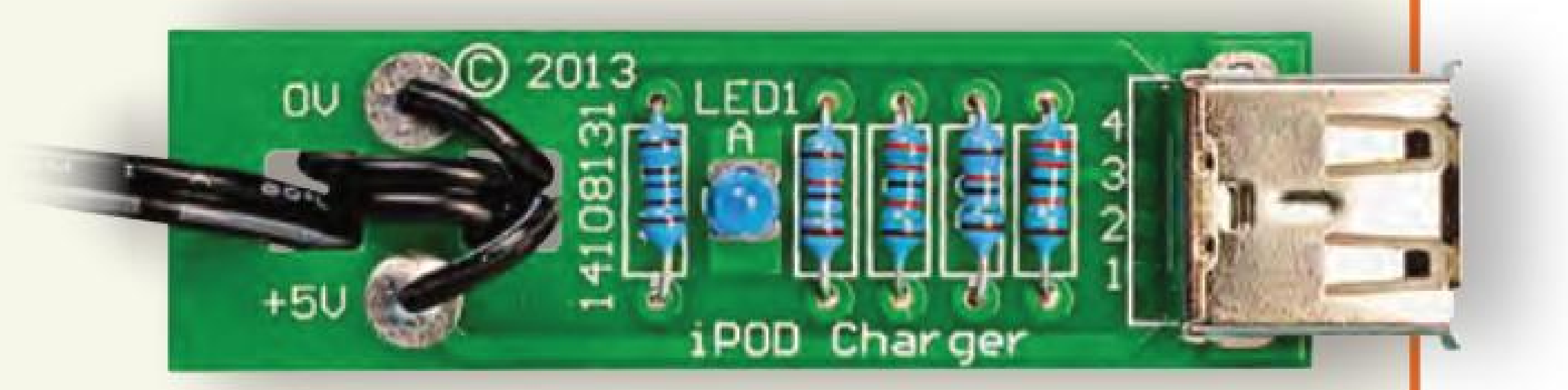


Fig.3: power can come from a 5V DC plugpack or from a USB supply (eg, a plugpack with a USB outlet). The diagram below shows how to connect a USB cable to the adaptor PCB.



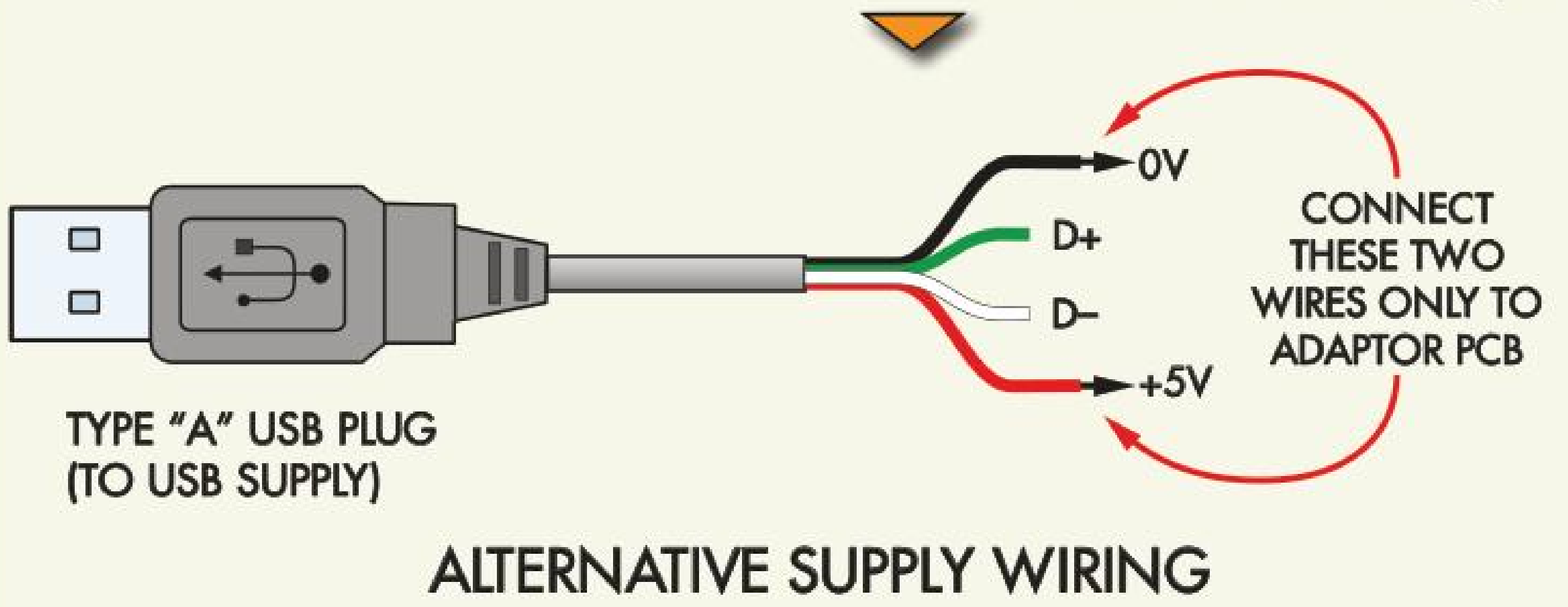
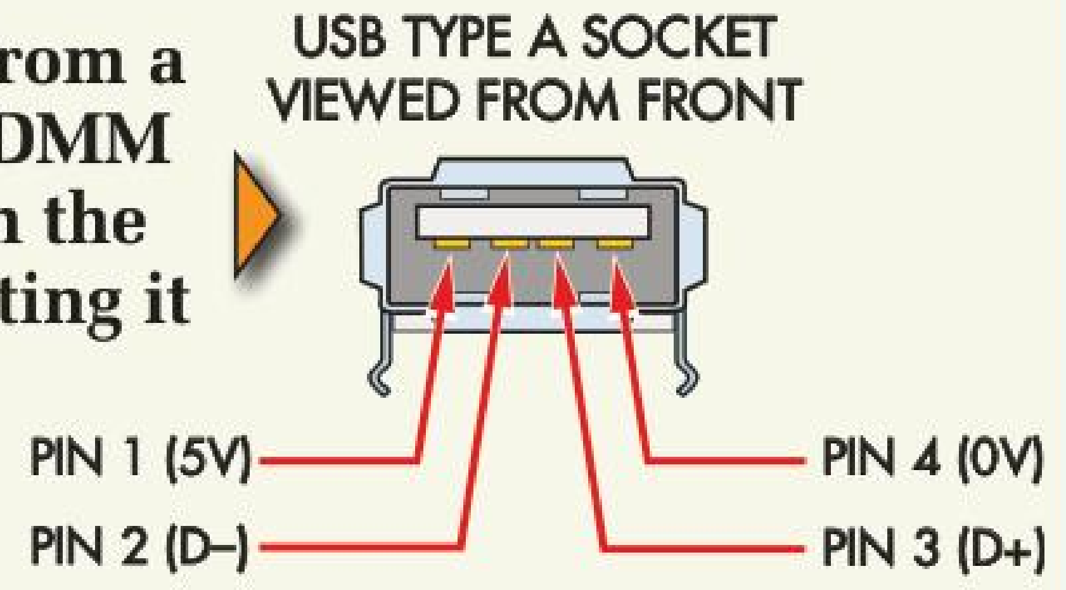

0V
D+
D–
+5V
CONNECT THESE TWO WIRES ONLY TO ADAPTOR PCB
TYPE "A" USB PLUG (TO USB SUPPLY)
ALTERNATIVE SUPPLY WIRING

Fig.4: the pin connections from a type 'A' USB socket. Use a DMM to check the 5V output from the adaptor PCB before connecting it to an iPod.



white and green data wires must be cut short and insulated so they can not short to each other or to any other parts. Table 2 shows the wire colours in a USB cable.

Alternatively, you can use a USB type 'A' line plug and connect this to the PCB via a length of light-duty figure-8 cable.

Checking output polarity

It's imperative that the output polarity from the adaptor is correct. This means that after connecting the *iPod Charger Adaptor* to a 5V supply, you should check the polarity at its USB output socket before connecting it to an iPod. In addition, if the incoming supply polarity is correct, then the indicator LED will be lit (provided it has been installed the right way around).

Table 2: USB cable colours

Pin	Wire colour	Name	Function
1	Red	V_{CC}	+5V
2	White	D-	Data -
3	Green	D+	Data +
4	Black	GND	Ground

Fig.3 shows the pin connections as viewed from the front of the USB socket. Using a multimeter, check that pin 1 is at +5V and that pin 4 is 0V (both with respect to the 0V pad on the PCB).

When you are certain that the supply polarity (and voltage) is correct, the adaptor can be used with your iPod. You should be greeted by a charging indication when the iPod is plugged in. If charging does not take place or you get the 'charging is not supported with this accessory' warning, check the iPod model that you have and check that the correct resistor values have been used for R1-R4.

Once everything is working, the resistors can be resoldered and the PCB covered in heatshrink tubing. If you do not have clear tubing, then used coloured heatshrink and cut a small slot in it for the LED to protrude through before shrinking the tubing down with a hot-air gun.

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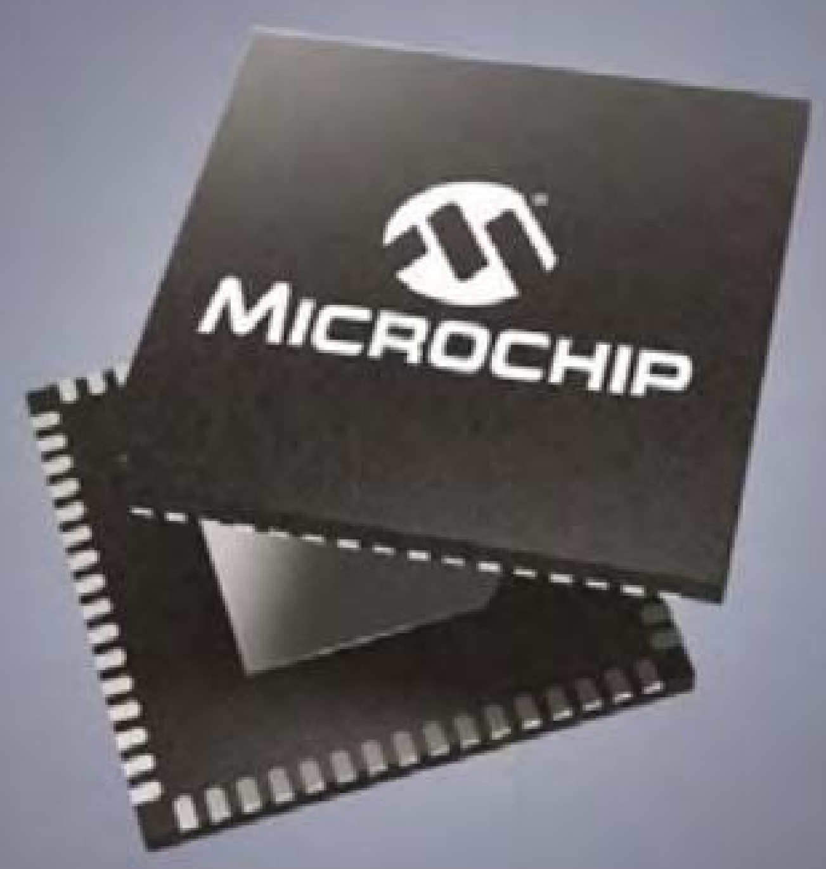

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PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Adding SPI capabilities and graphics LCDs

A microcontroller is not much use without things attached to it, and when attaching intelligent peripherals to a microcontroller one of the more popular standards is the Serial Peripheral Interface bus (SPI). This interface is similar to a UART serial bus, with the exception of two additional signals – a chip select line used to select a particular device (multiple devices can be connected to the SPI bus) and a clock signal, used to time the transmission of data bits.

When communicating over the SPI interface the microcontroller is the 'master' device, generating the clock signal that controls the rate at which peripherals communicate. This has a number of benefits over a UART interface: the processor does not need an accurate oscillator, and the peripheral communication hardware can be quite 'dumb', perhaps nothing more than a shift register. For a very simple device like a temperature sensor this can significantly reduce the cost of the hardware.

Multiple devices

Multiple devices can share the same bus, although only one 'slave' device can be addressed at any one time. The active device is selected by enabling its chip select pin. An example bus configuration, connecting a microcontroller to a number of slave devices is shown in Fig.1.

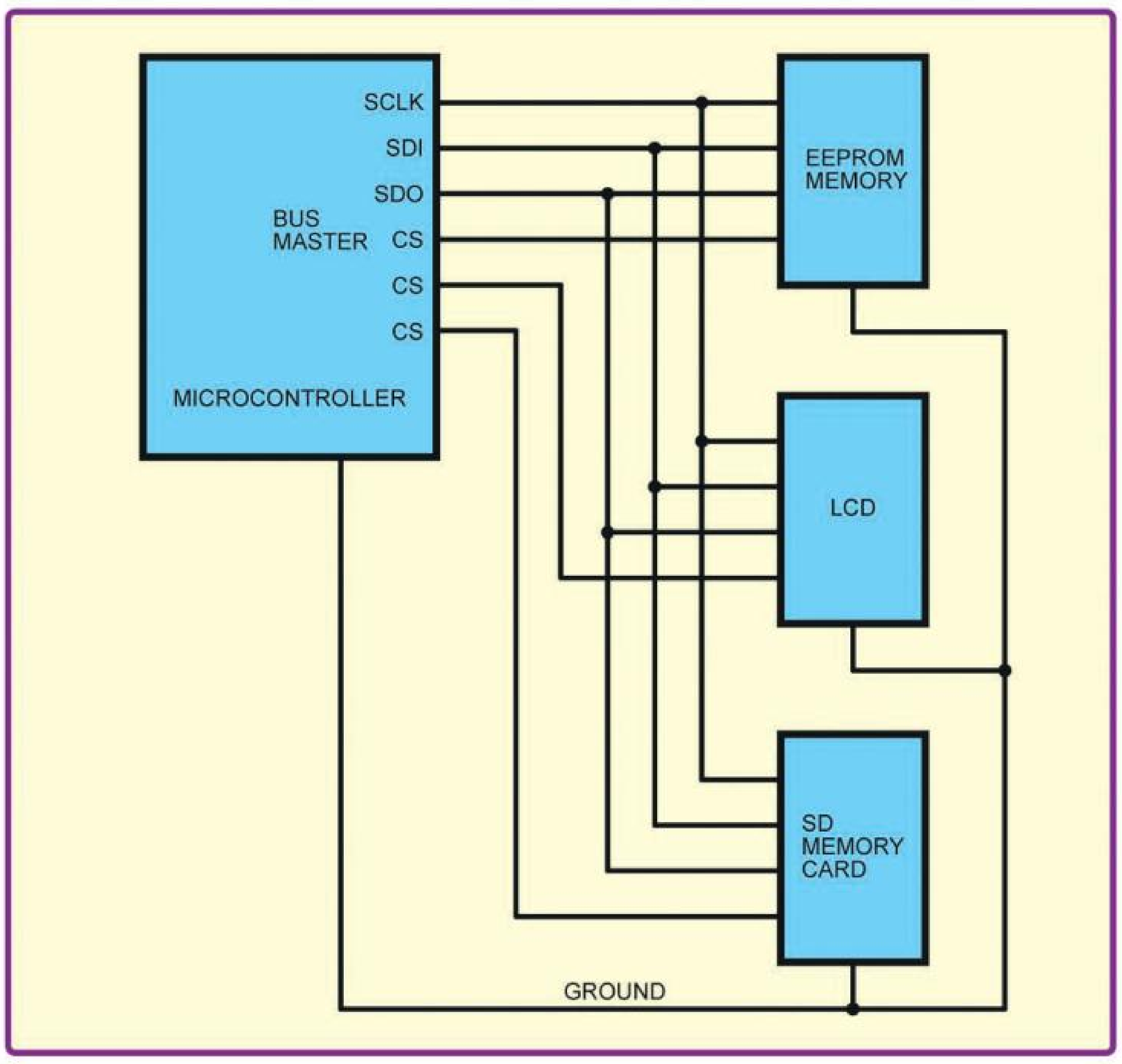


Fig. 1 Example SPI Bus

There are many different types of devices that can communicate via the SPI bus, including graphics displays, SD Media cards and a wide range of sensors. The bus is easy to hook up using only four wires, and so long as you can cope with a relatively slow interface speed (typically up to 10Mb/s) then it's ideal for prototyping on breadboard. Our processor has an SPI controller built into it, so it makes sense to use the SPI bus to talk to peripheral devices.

There are some quirks to the bus interface which we will pick up on in a later article; for now, we will talk through an example – hooking up a small, low cost colour graphics LCD.

Colour LCD

A quick search on eBay for '1.8-inch colour LCD' will reveal a variety of cheap displays. Once used in mobile telephones (and therefore manufactured in huge volumes) they are available now either as a result of excess stock or a manufacturer making use of an efficient manufacturing process to turn them out for hobbyists at a low cost, while the interest in them lasts. The key point is that the availability of these displays will be volatile – don't expect to be able to buy the same display a second time, as it may no longer be manufactured. For 'one-off' hobby use, however, this is not an issue.

These modules differ from the popular character LCD displays (based on the decades old 44780 LCD controller chipset) in several ways. Whereas the 44780 controller IC used on those displays is well known and well documented, modern mobile phone graphics LCD controller chips change rapidly, and are normally incompatible from one LCD panel to the next – sometimes even on the *same* part numbered display. It's one of the downsides for hobbyists purchasing high-volume manufactured parts; for the original mobile phone manufacturer, if another supplier comes out with an incompatible display that is a few pennies cheaper, it can still be worth the investment to re-write the lower level software interface and change to the new, incompatible part.

The main impact of this on hobbyists is that when you buy a low cost full colour LCD panel on eBay, make sure you get the datasheet and some example code. Why the code? Why not just a datasheet? It's because, in our experience, the technical information released with these products is *terrible*. Even for the device we are using here, the datasheet is poor. It's no great surprise; these modules were probably produced for a single customer, and with such a short product life there is no value in investing a huge amount of time in producing quality documentation. The ubiquitous 2×16 character LCD has been with us for so many years that the documentation on it has improved over the years, almost through osmosis.

So are cheap colour LCDs to be avoided? Certainly not. If you are making a project for yourself and a few friends the risk – the risk of getting a device that you cannot program – is pretty low, and at the worst you have lost a few pounds. It's worth taking the risk.

Software

We purchased a board based on the 'Truley 128 × 160 colour LCD' module. The board provided a simple 0.1-inch pitch SIL connector (which mounts easily onto breadboards) and even adds an SD Media connector on the back. A great combination, and all for £4 delivered. The display's controller chip – the device we actually communicate with – is the Sitronix ST7735S. Crude interface software was provided by the supplier, and a scan of the Internet showed a number of different implementations of the software interface available in the 'C' programming language. Although these were for a different processor type (ARM) it was easy to convert so we knew we wouldn't be left in the dark with this display. That's another plus point for programming in the 'C' programming language. It's easy to re-use.

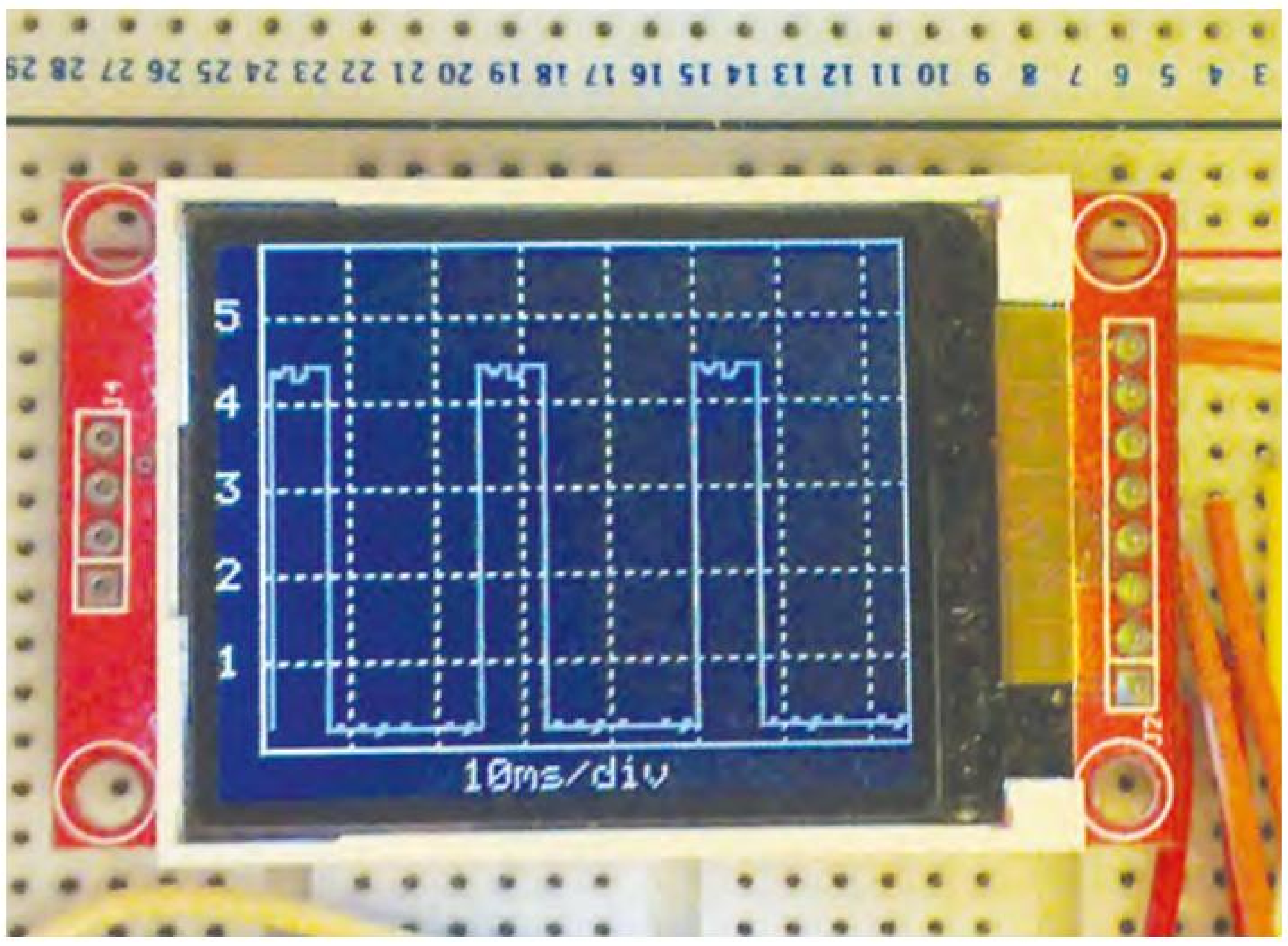


Fig. 2 Colour graphics LCD on a breadboard

It's important to get some example code, as there is a lot that can go wrong when trying to talk to these kinds of displays. There are normally a few tens of bytes of initialisation data that need to be written to the display controller to get it running before you are presented with a pixel based interface. A few low-level routines are required for performing pixel setting and 'window' definition access for the display directly using SPI commands, then higher level API routines for line, circle and text-based functions call on those routines. These higher level routines are often highly portable and can be re-used on different LCD displays. The low-level routines are the ones that must be provided if you have any chance of getting a display running.

It's good to see that even now, two months after purchasing the display that similar modules are still available on eBay. It's a great little display. You can see ours in action in Fig.2.

Physical interface

If you are buying a different display take care to find one with a physical interface that you can actually work with – some are designed to be affixed using fine pitch connectors or heat bonded tabs and these require assembly techniques that are beyond the typical hobbyist capabilities, and are to be avoided. Suppliers will not ask you whether you have the tools to use these displays. It's your responsibility to know what you are doing.

At the other end of the spectrum, some displays are equipped with 2 × 20 0.1-inch pitch connectors – fine if you are designing your own PCB, but of no use if you want to use a standard breadboard prototyping setup, as in Fig.2. The LCD panel we used this month is equipped with a 0.1-inch pitch SIL header ('Single In Line') that fits easily into a breadboard.

Look out for modules that require a single, 3V interface. It's not unusual for colour LCDs to require larger on-module voltages and some displays require you to provide these voltages yourself, which can sometimes double the cost of the display solution. Well-designed modules have on-chip voltage multipliers requiring nothing more than an external capacitor, and sometimes not even that.

With displays like the one we purchased there are fewer wires to hook up than for a 16 × 2 character LCD, and no contrast trimmer resistor required. These displays are *really* easy to work with.

Be certain that the device you are purchasing has a microcontroller- friendly interface, as some are 'raw' interfaces with no built-in controller. The tale-tale signs are if the display interface has HSYNC or VSYNC input signals. These displays expect to be connected to an external display controller, and will not work with a microcontroller directly.

Controller capabilities

An LCD module consists of two components: the glass TFT display, and a powerful controller IC usually mounted on the glass itself, that provides the link between the glass and the microcontroller. The controller IC typically connects to the circuit by a heat bonded flexible connector, which for hobbyist use is then connected to a small 'carrier' PCB that provides a physical support for the display and a user friendly pin head connector. Our PCB also carries an SD Media socket; handy, as colour LCD displays are often used to display images and complex user-interfaces, so somewhere to store those images is a welcome addition.

In the vast majority of cases, graphics LCDs present a simple 'bitmap' style programming interface to the user. In otherwords, no text drawing routines – you must provide these yourself, specifying the font yourself. Thankfully, this kind of software is readily available on the Internet from a variety of sources and a search for '5 × 7 font' will find a number of solutions to the text drawing problem.

The processor communications bandwidth to the display is higher than for a simple character display. You are writing individual pixels rather than complete characters which requires about six times as much data to be transferred – so the speed of your interface is important. There is nothing worse that a slowly updating display!

While the orientation of the display (ie, the direction in which you draw text and graphics) is entirely up to you, drawing in the 'default' direction will always be quicker than any other direction as the controller hardware has been designed for one specific case. Some displays – and ours is no exception – provide specialised functions for drawing in smaller pixel rectangles to help speed up drawing text; these functions are more dependant on the particular controller in use. So, understanding the particular controller on your specific board is very important. The datasheet for our display is two hundred pages long, so you can appreciate that getting sample code for the display is essential.

We've taken the sample code provided with the display module and tidied it up a bit, making it compatible with the PIC programming language and adding a standard 5 × 7 font. We chose to implement the SPI interface in a bit-bashed manner as it was simpler and more portable. In a later article we will make use of the processor's built-in SPI peripheral and see what kind of speed improvement can be achieved over a bit-bashed one.

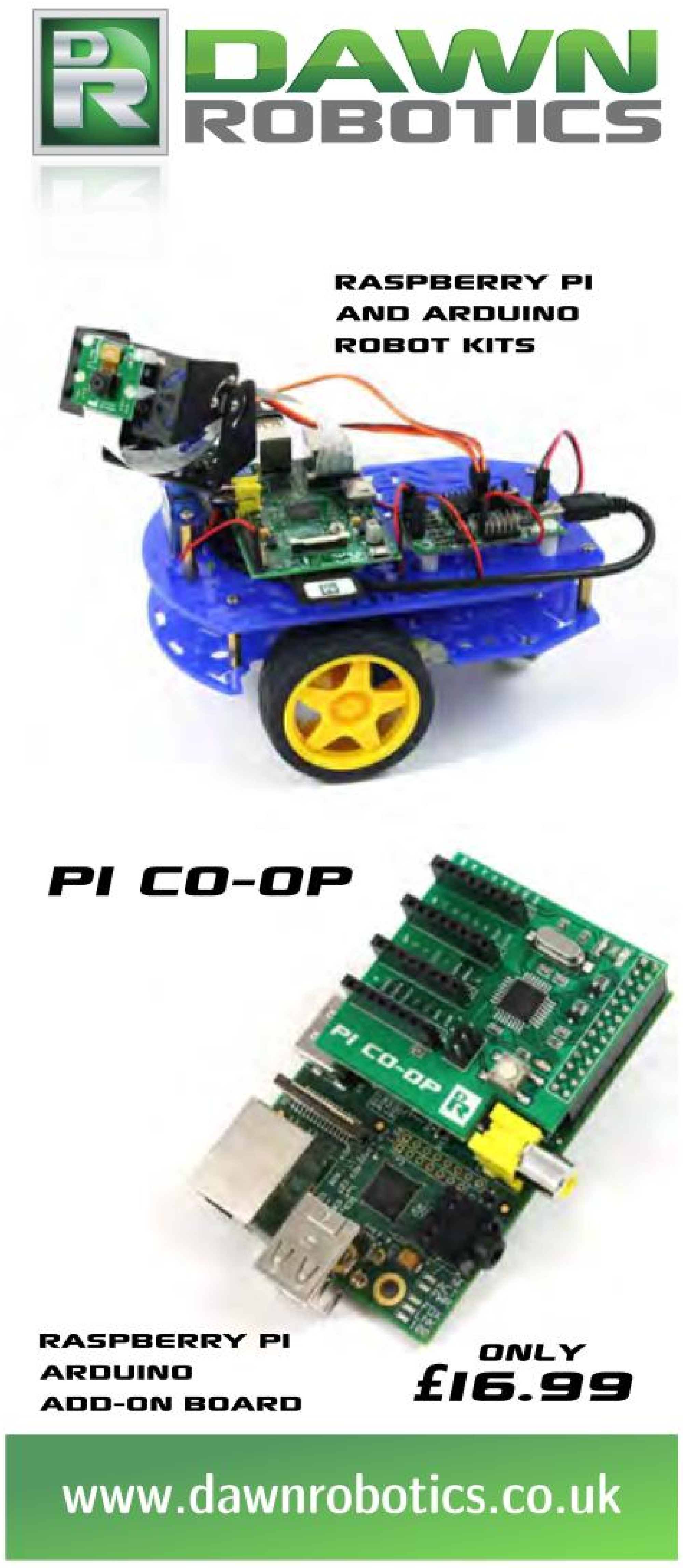
Kickstarter progress

For those of you who have been following our Kickstarter campaign, the current status is that (as we write this article in late May) the initial 'Early Bird' prototype development boards have been shipped, as planned. By the time you read this article the final hardware will have been delivered and the next Kickstarter will be underway. We will cover the full Kickstarter project in a separate article later on.

Next month

Next month, we take a detailed look at the SPI interface, covering the specifics of interfacing to our LCD display and how the bus can also be used to connect to a Bluetooth module.

Not all of Mike's technology tinkering and discussion makes it to print. You can follow the rest of it on Twitter at @MikeHibbett, and from his blog at mjhdesigns.com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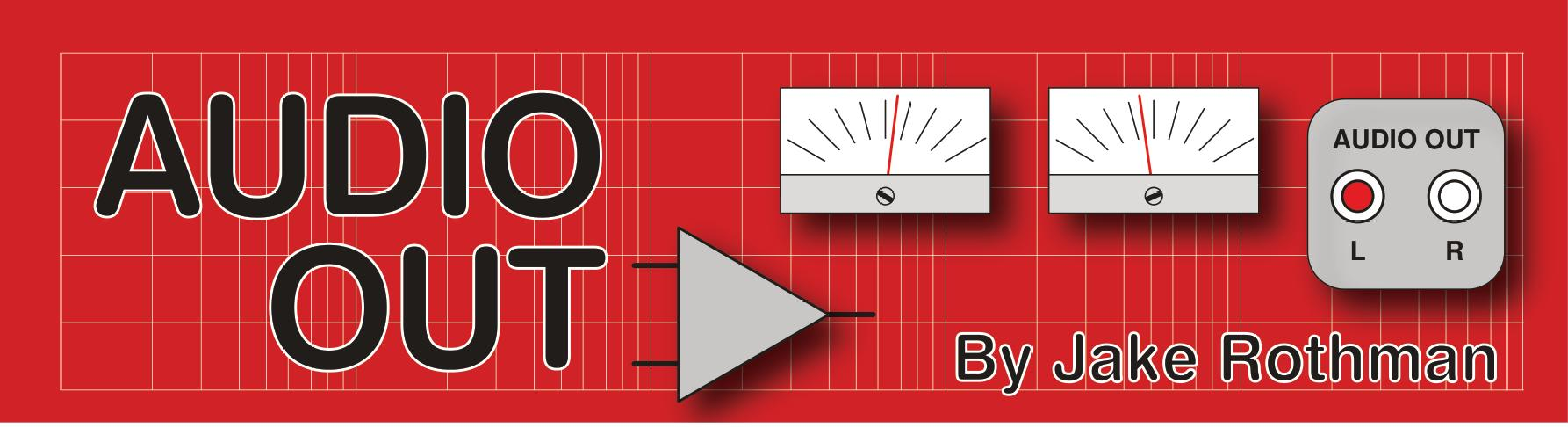

AUDIO OUT

By Jake Rothman

Eradicating wet electrolytic capacitors from audio circuits – Part 1

ANYBODY involved in the practical side of electronics will have had trouble with electrolytic capacitors, especially the small wet types that are sprinkled all over audio circuitry. The drying-out problem of electrolytics has been well known since their introduction. Added to this is the 'capacitor plague' legacy and the problem of explosive end-of-life failure in low-ESR wet electrolytics used in switch-mode power supplies. The solution to these issues is to use solid-electrolyte capacitors, such as solid-tantalum, solid-aluminium or polymer types. With today's wonderful solid-state technology, it does seem a shame to ruin a circuit's reliability with small cans full of soggy tissue paper sealed with a rubber bung!

Life expectancy

There's no need to get rid of *large* wet aluminium smoothing capacitors in power supplies – these are not the problem. They have a large internal volume of electrolyte relative to their surface area/seal leakage rate, so they last for years. It is the small radial types that dry up and fail. Some small axial types, such as the Rifa PEG124 series (Fig.1) and the Philips/Vishay 108 series last a long time, since they have only a single lead riveted into the case; the metal case itself forms the other lead. Seal leakage rate tends to be random, so banks of paralleled capacitors help avoid total failure. I do this when building large bi-polar speaker coupling capacitors to protect the speaker against DC faults and excessive low frequencies. Even your average wet capacitor is more reliable than a relay and its associated circuitry. A speaker protection capacitor built with four 470µF 35V bi-polar wet electrolytic capacitors is shown in Fig.2.

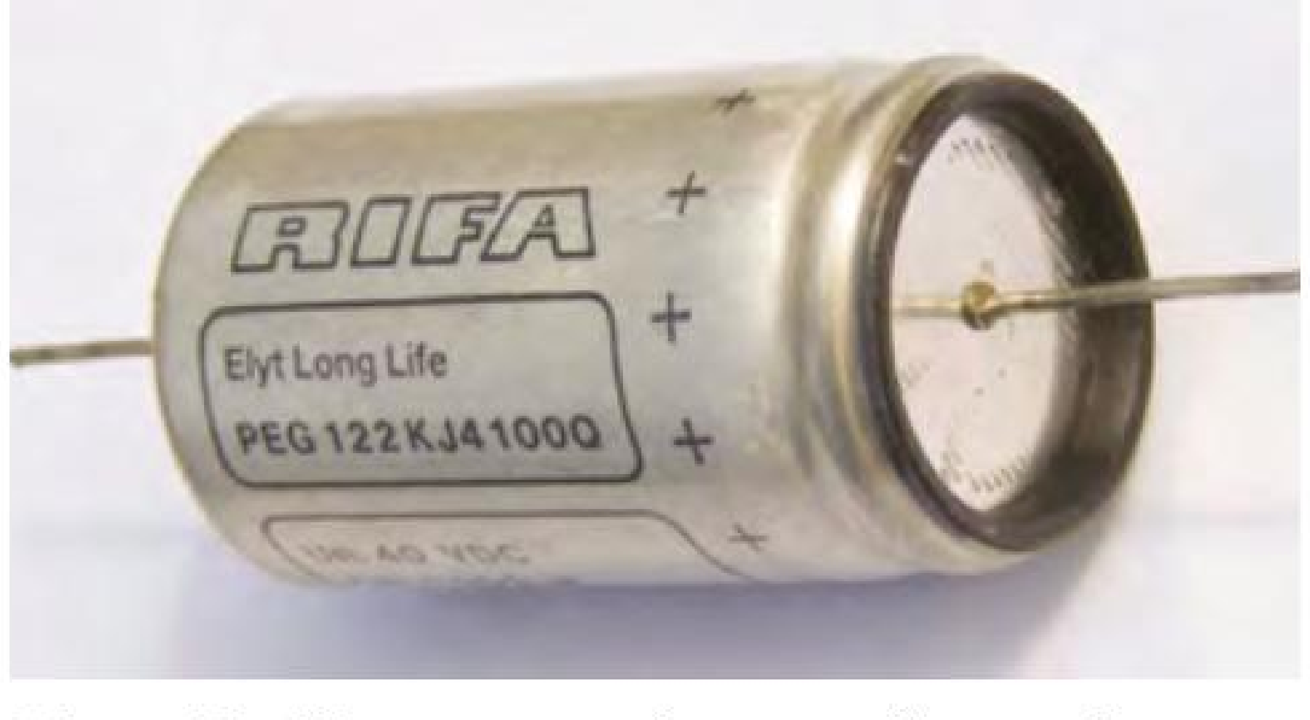

Fig.1. Unlike many other small wet electrolytic capacitors, the Rifa PEG124 axial range is designed for long life

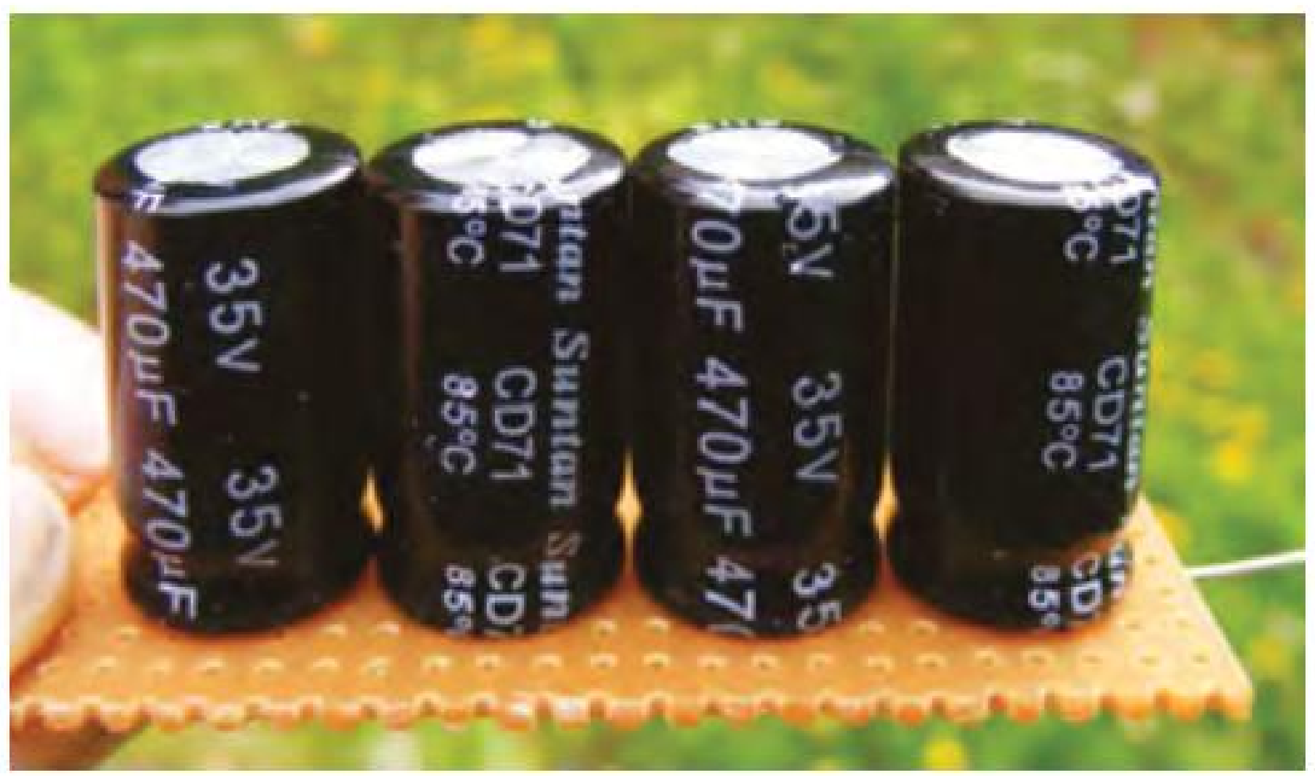

Fig.2. To increase reliability, this speaker protection 'capacitor' is actually built with four 470µF 35V bi-polar wet electrolytic capacitors

In the rare event of failure, solid-capacitors go short-circuit and it is sensible to consider this in the design. Wet types tend to go open circuit gradually, a less damaging mode. In the worst case, some tantalum types can catch fire. However, if used properly, solid capacitors greatly improve general circuit reliability. This is why they have been the norm in avionics for years. Metal-cased hermetically sealed tantalum types (Fig.3) can go on for over 50 years – a fact very much reflected in their high cost. If you see any of these going cheap, then snap them up, even if they are date coded 1968 onwards, they will still be perfect because of their long-term stability. Spectrasonics are one of the few music companies to have always used them.

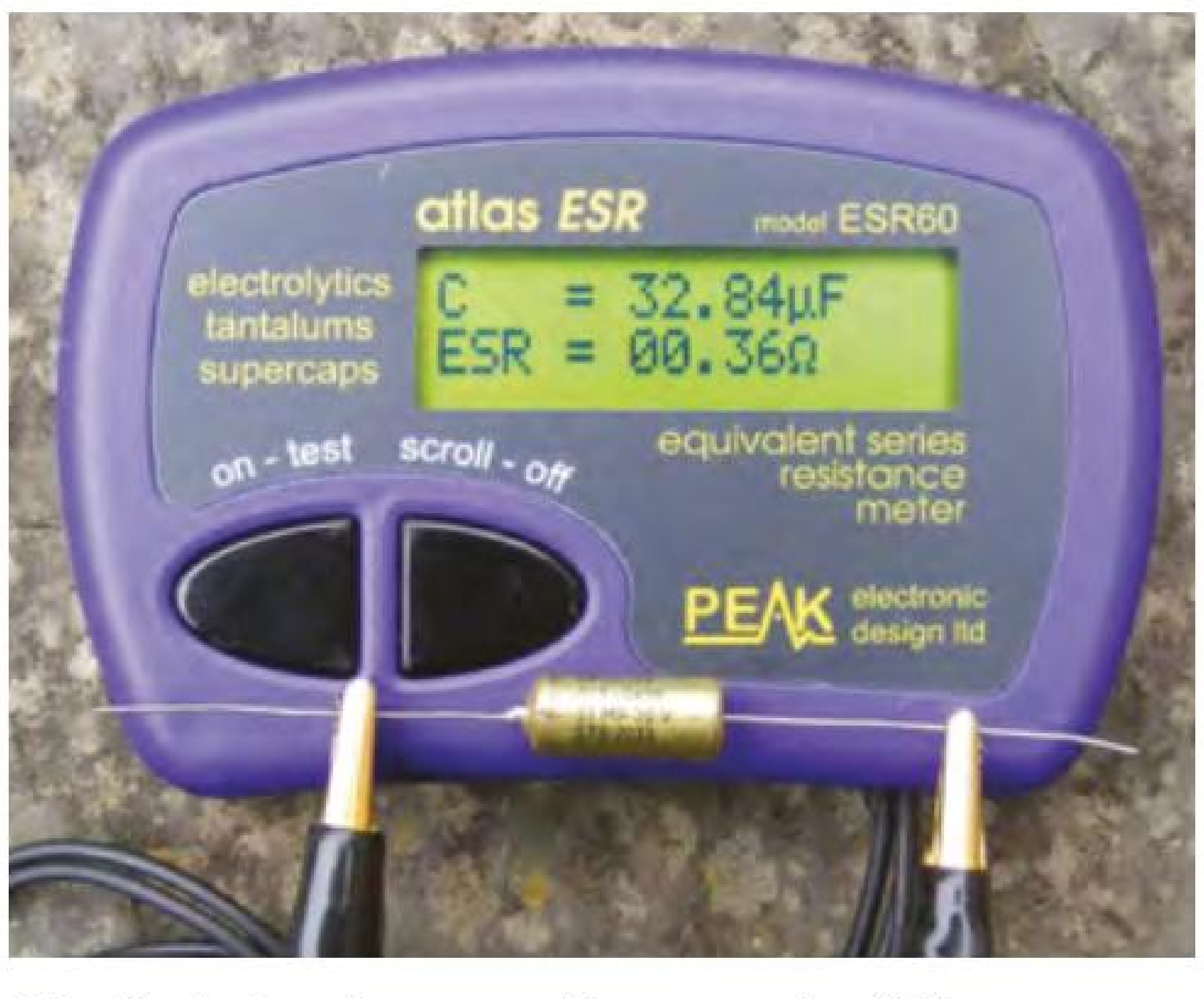

Fig.3. Avionic capacitors are built to a much higher standard with upwards of 50 years of life expectancy. Snap them up if you find them going cheap! This example is of 1970 vintage

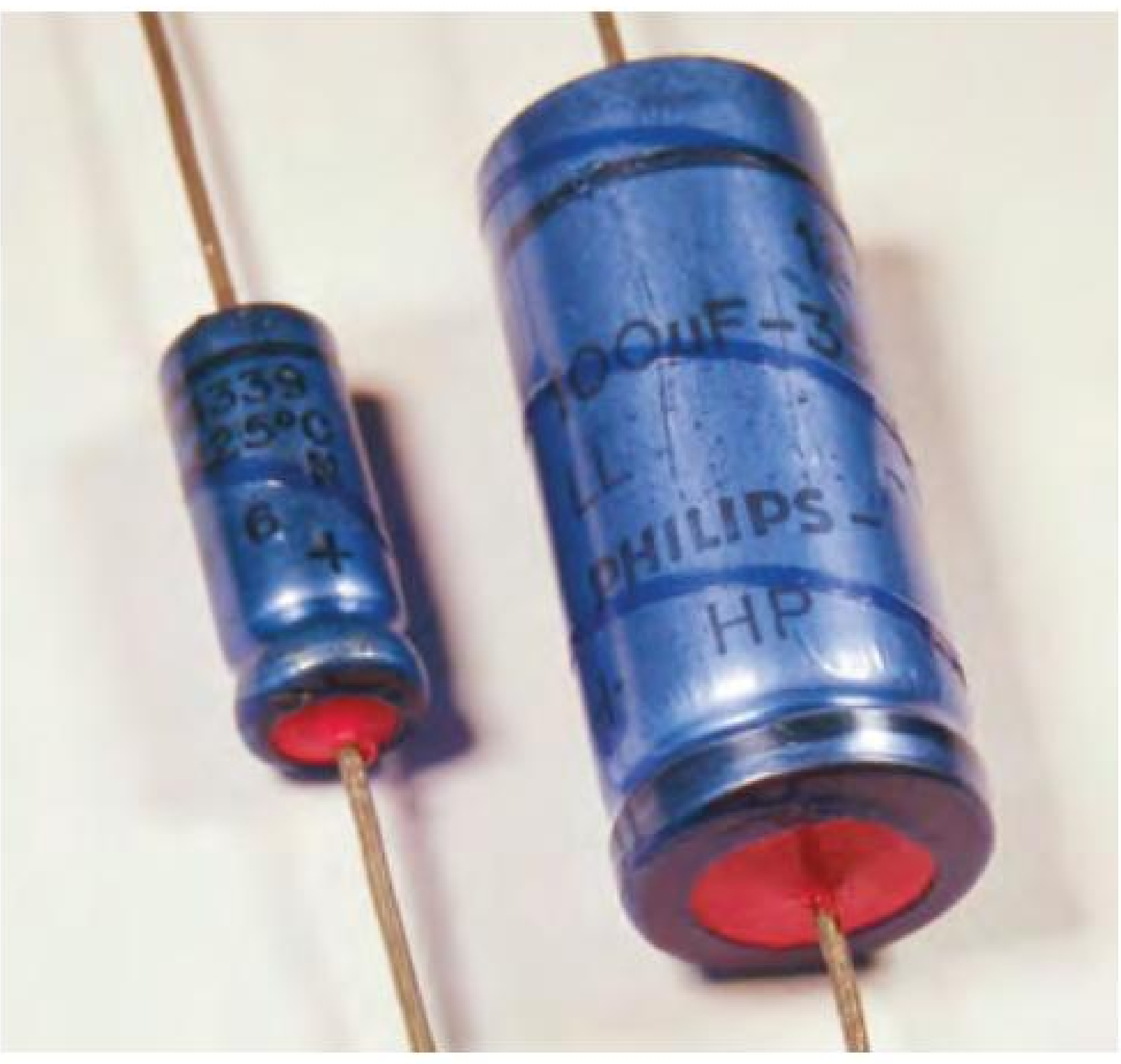

Fig.4. Examples of the Philips 121 and 123 series of manganese dioxide solid-aluminium (SAL) capacitor (the red seal indicates they are members of this long-life family)

Philips introduced the manganese dioxide solid-aluminium (SAL) capacitor in 1964. The 121 and 123 series could also last 50 years plus (see Fig.4, note red end seals). They are rated for 20,000 hours at 125˚C. These are the toughest polarised capacitors available. I use them for cathode bypass capacitors in hot valve amplifiers. There is also a dipped radial version that looks like an orange pearl. Once SAL capacitors were cheaper than tantalum, but they are now expensive, since they are single-sourced from Vishay. Come the next tantalum shortage, they may become cheaper again.

Heat

In most studios and industrial environments it is common practice to leave equipment on all the time in racks, which speeds up the drying out process. According to Arrhenius, every 10˚C temp rise doubles the rate of reaction. From this rule of thumb, you can calculate an approximate expected lifetime of a device. So, a 2000-hour

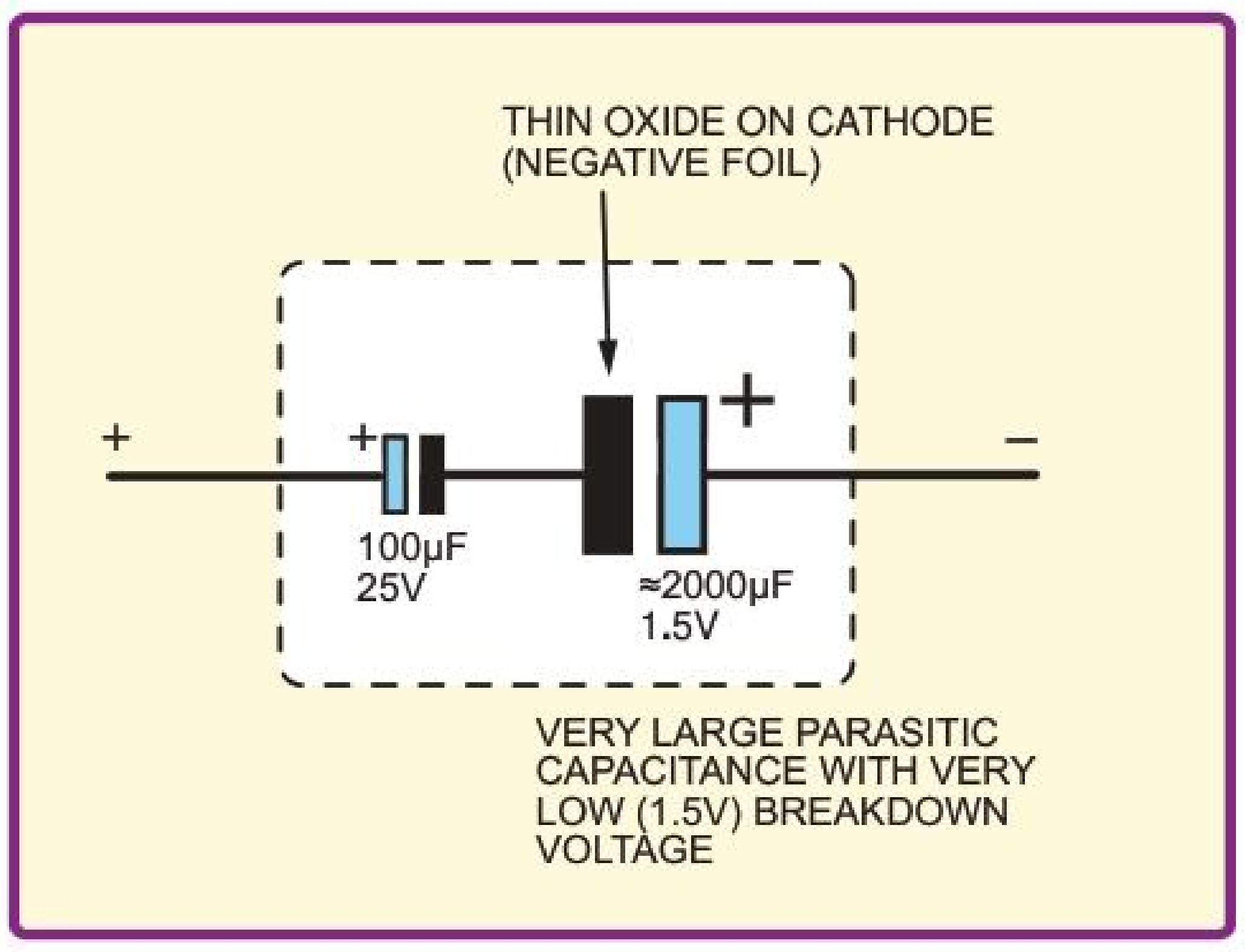
THIN OXIDE ON CATHODE (NEGATIVE FOIL)
+
+
–
100µF 25V
≈2000µF 1.5V
VERY LARGE PARASITIC CAPACITANCE WITH VERY LOW (1.5V) BREAKDOWN VOLTAGE

Fig.5. Equivalent circuit of a dual-foil polarised 100µF electrolytic capacitor

capacitor at 85˚C will last 4000 hours at 75˚C. High ripple current and the resulting internal heat generation is an additional life-reduction factor. Solid capacitors generally last 64,000 hours or more at 75˚C.

Distortion

It is often claimed that wet aluminium electrolytic capacitors are non-linear – but if they are used correctly, so that almost no signal voltage appears across them, then insignificant distortion is generated. The distortion level is still a few times worse than that of film types, however. This means setting the cut-off frequency in coupling applications excessively low (around 2Hz) to avoid a rise in distortion at low frequencies. In turn, this means large values, often around 47µF to 1000µF. The main cause of the distortion seems to be the large series capacitance of the unformed cathode foil, which has a very thin oxide layer due to atmospheric oxidation. The breakdown voltage of this oxide film is 1.5V and any significant voltage across it results in distortion. This is illustrated in Fig.5. It also provides protection from momentary voltage reversals. Note that solid tantalum capacitors do not have this feature. This is why I used a solitary blue power-rail wet-electrolytic decoupling capacitor among the Kemet moulded tantalum capacitors in my Colorsound Power Boost pedal in Fig.6.

The technique of oversizing has been popularised by respected audio designer Douglas Self, and is now standard in the industry because it is cheap and effective. However, it does result in higher leakage currents and longer stabilisation time when the circuit is switched on.

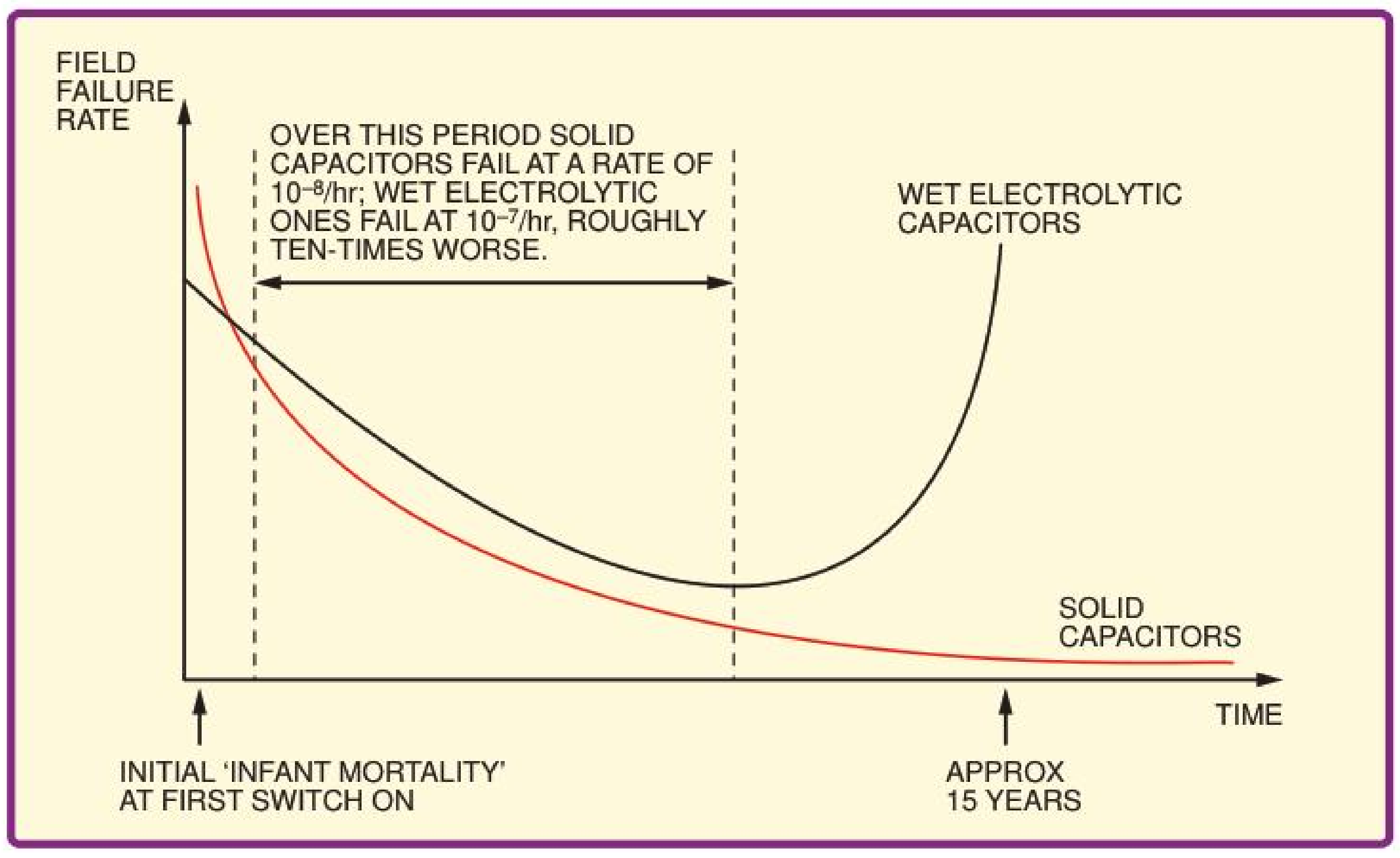

Fig.7. Qualitative graph showing the relative failure rates of wet and solid electrolytic capacitors

Bi-polar electrolytic capacitors

Bi-polar electrolytic capacitors have fully formed foils for both plates, so the 'thin oxide' distortion problem is eliminated. They have much less distortion, almost on a par with polyester-film capacitors, so smaller values can be used. Cadac mixers and some hi-fi manufacturers use this type, but the drying-out problem is still an issue.

Re-capping

Capacitor replacement in mixing desks and other audio equipment is such a labour-intensive job that a local studio (Giant Wafer) bought me a £400 Denon SC7000Z de-soldering gun to assist in re-capping their Soundcraft desk, which contained a few hundred dried-out radial electrolytic capacitors. This has now become a small industry, because studio owners are so worried about capacitor failure. I see it as a marketing opportunity – 'no wet capacitors inside'.

It is worth pointing out that to make any money doing servicing, you have to charge around £20 per hour for labour. I find it embarrassing writing on the invoice, 'Labour £40.00, Parts, 20p for two 100uF 10V electrolytic capacitors'. It's better to spend more on capacitors that don't dry up in the first place. Solid capacitors are generally three to ten-times more expensive than wet types, but in high quality equipment, it's the life-cost that matters. The old engineer's adage applies, 'it costs 20p for the part, 50p to solder it in, £5.00 to replace it' plus transport. Analogue music equipment is a mature technology, a long service life of 30 years is typical. Interestingly, the failure rate of solid tantalum capacitors decreases the longer they have been in service, there is no wear-out mechanism, see the graph in Fig.7.

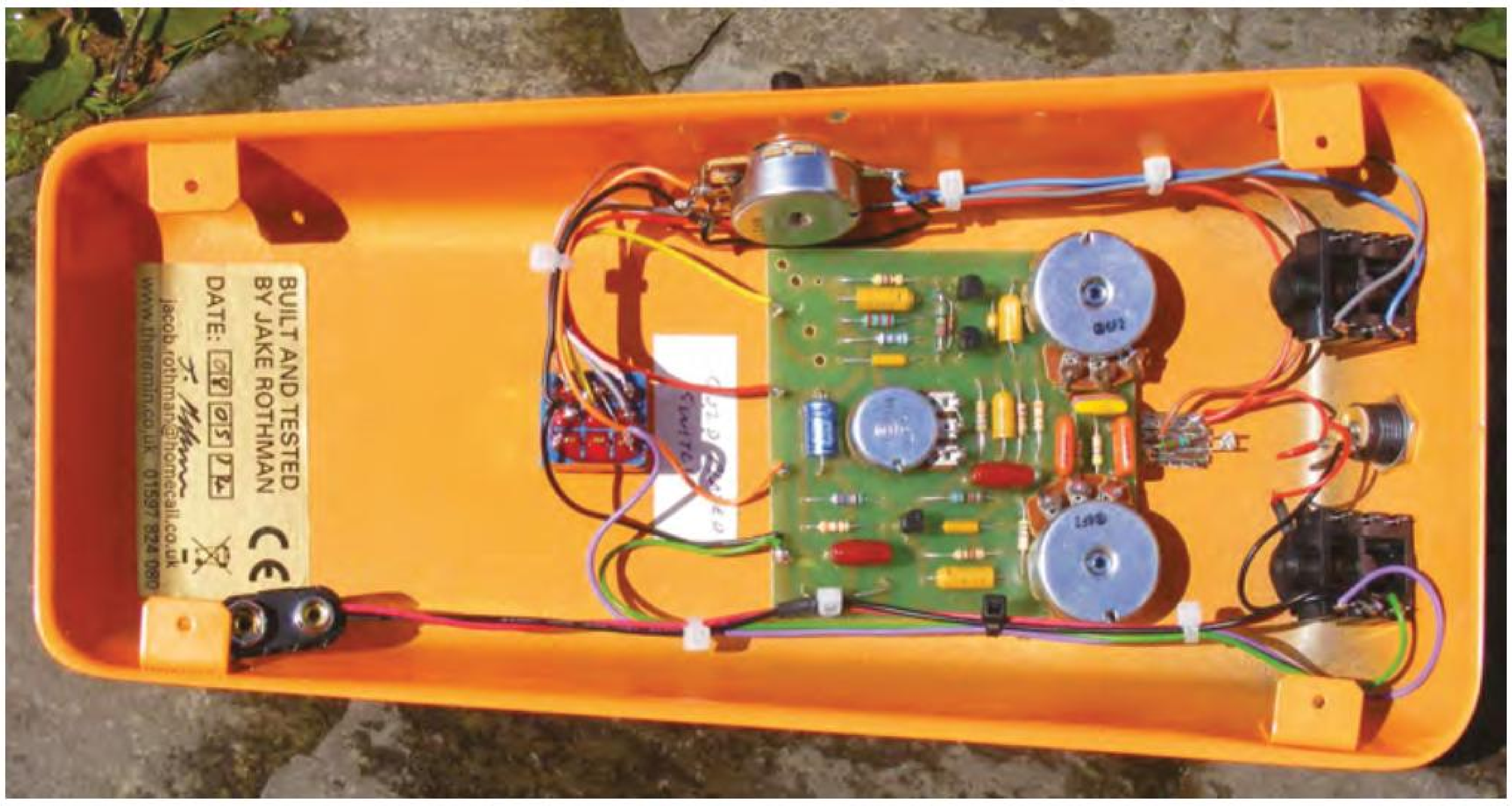

Fig.6. Note the blue wet electrolytic capacitor, centre left on this Colorsound effects pedal. It was included in this audio circuit because sold electrolytic capacitors do not offer the momentary reverse polarity protection of wet electrolytic capacitors

Polymer capacitors

Polymer capacitors are an improvement on older solid capacitors that use manganese dioxide. The best ones still use tantalum, but the cathode is now a semiconducting polymer which has a bulk resistivity that is 10 to 100 times less than manganese dioxide, giving much lower loss. They are loved by computer buffs; Apple computers and Nvidia graphics cards were where I first saw them.

Lower process temperatures are used and the resulting polymer is a softer material. These factors reduce the stresses the tantalum oxide film is subjected to, which increases their reliability. The first commercially successful design was the Sanyo Os-Con, which used wound aluminium foils, introduced in 1983. Panasonic now makes these.

It's a rip-off

Note that because analogue parts are a slow growing market, there have been numerous mergers between companies, such as ITT and STC – absorbed by AVX. Vishay is buying up many of the old 'classic' parts lines, such as the Philips, BC components and Sprague ranges, and Kemet has absorbed Rifa.

A consequence of this reduction in competition has been price rises. Conversely, polymer types are getting cheaper, since there is competition.

The pure tantalum powder required for capacitor production costs around $450 per kilo, which is much more expensive than aluminium foil. There was a bad tantalum shortage in 1996, retail prices went up, but unfortunately never came down again.

ESR

ESR (equivalent series resistance) is an important property in high frequency decoupling, and can be measured with many component meters (see Fig.3). Most manganese dioxide capacitors are quite poor in this respect and it is a wide tolerance parameter. It is usually specified as a maximum, and in practice is often a quarter of this figure. It does not matter for low frequency 50Hz to 100Hz power supply designs and AF (audio frequency) coupling, since the reactance of the capacitance will be higher, and hence the ESR is insignificant.

Timing circuits will often have a very large series resistance, and the lower leakage current of tantalums will give much more consistent results. I use 220µF 10V Nichicon RNE polymer capacitors in my Theremins for decoupling. They mop up all the residual RF because of their low ESR. This stops the oscillators from locking together. At 16p (100 off) from Mouser, there's no point using wet types.

Militant rant!

Anyone who scans the music audio forums, such as Gearslutz, will know tantalum capacitors are not popular in audio circuits, it is said they produce levels of distortion around ten-times higher than wet electrolytic capacitors. This distain for tantalums seems to equal that reserved for multilayer Y5V and X7R ceramic capacitors, which have considerable voltage-induced capacitance modulation. The voltage coefficient of tantalum capacitors is much less, so this effect was not the mechanism.

Cyril Bateman's articles in *Electronics World* in 2002, the definitive work on capacitor distortion, described how he gave up on tantalum capacitors, considering them 'not worthy of further testing'. H Baggot in *Elektor* (February 1992) said, 'tantalum capacitors are not really suitable for processing audio signals, owing to their construction they exhibit semiconductor effects'. I decided to get out my 'scope and trusty old *ETI* John Linsley-Hood distortion box and do some tests for myself. For once, the 'subjective' and 'objective' audio fraternities were in agreement. I found tantalum capacitors added about 0.01 to 0.1% second and third-harmonic distortion, which got worse as the frequency decreased. (Note that this distortion result was a hundred times worse than that caused by 5532 and LM4562 op-amps used in most pro-audio gear.) I also found polymer capacitors (Fig.8) had the same problem. One day I'll get an Audio Precision analyser to look at subtle effects.

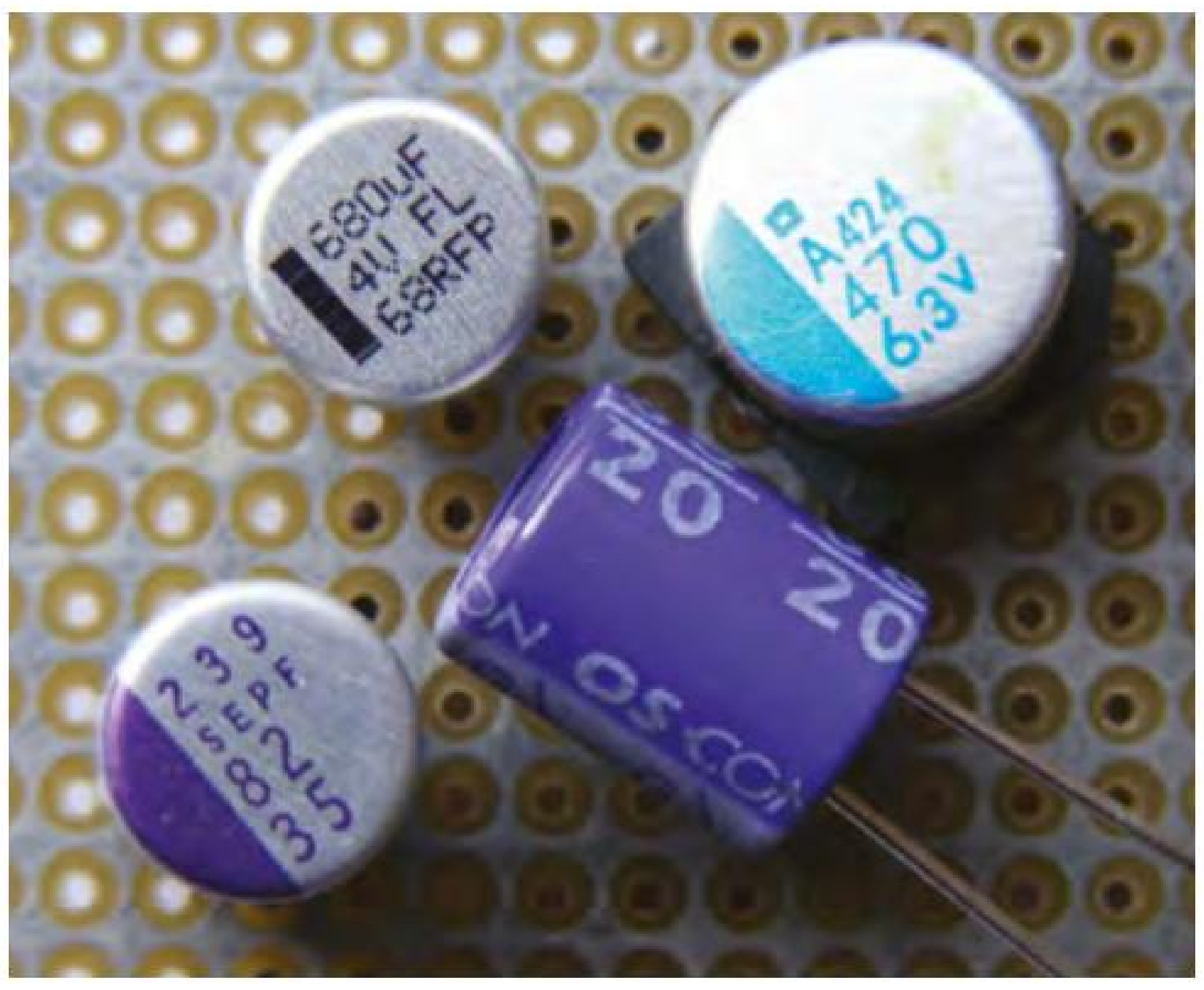

Fig.8. A selection of polymer capacitors

Coming up!

Next month, I'll talk more about solid capacitor distortion, the shorting problem, and how to incorporate solid capacitors successfully into your circuits and projects. See you in the next issue of *EPE*!

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By Robert Penfold

INTERFACE

Time and time again

TIMING external events using a computer and a simple interface is something one might reasonably expect to be a straightforward task. The reality is often rather different, with the timer functions of computer languages often being rather basic, or even downright crude with dubious accuracy and poor resolution. The facilities that are on offer are not generally aimed at timing in the outside world. With modern computers it can require a fair amount of interfacing in order to monitor one or two digital lines.

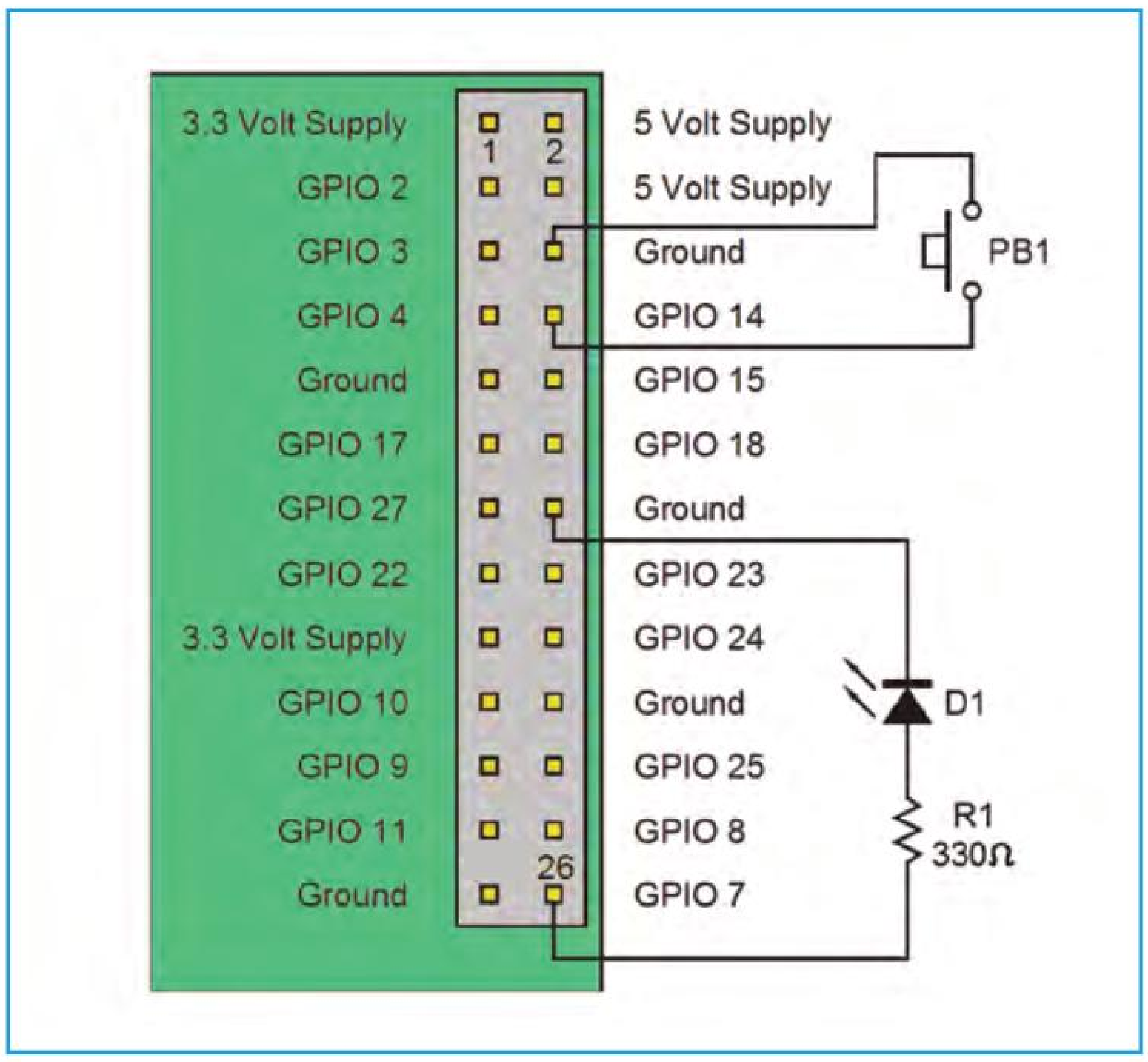


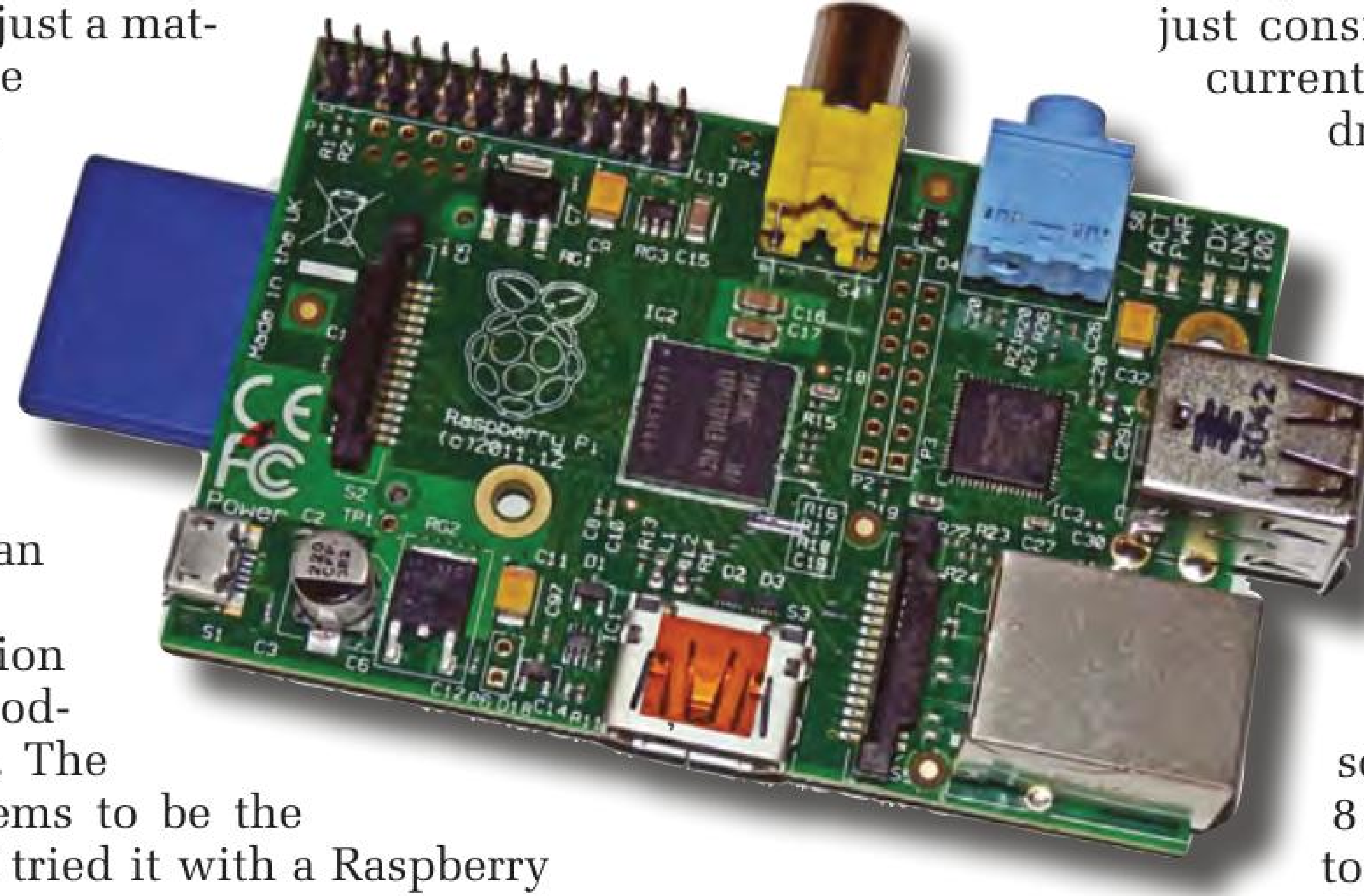
Fig.1. The only additional hardware needed for the reaction timer is a switch, an LED, and a current-limiting resistor. The switch is a normally open type, and it is operated as soon as possible after the LED switches on

From start to finish

The Raspberry Pi computer, when used with the Python programming language is relatively good in both respects, making interval timing reasonably straightforward. With its built-in interface there is no difficulty in using a few digital input lines to monitor signals that provide the start and stop points. The Python programming language has timing facilities that seem to offer good accuracy and resolution. A computer-based system is probably not the best option where accuracy to the nearest microsecond and beyond is required. Dedicated timing hardware is likely to give greater precision when this degree of accuracy is needed. However, for less critical applications the Raspberry Pi offers what will usually be a very simple solution.

There is quite a lot of information on the Internet about timing and the Python programming language, but much of this is concerned with accurate timing of code execution, rather than the timing of external events. However, some of the timing facilities available lend themselves well to general timing applications. The timing functions offered by the Python programming language vary in points of detail depending on the type of computer and operating system in use. This is simply because these timing facilities use operating system calls and the relevant underlying features of the operating system and the computer's hardware.

Fortunately, for simple timing applications these differences do not really matter too much. It does not matter whether the times provided are based on the time at which the computer was switched on, the notional time at which the operating system came into being, or any other starting point. It is just a matter of taking times when the measured event starts and finishes, and then deducting the start time from the finishing time. You obviously need to know the units in use so that the final figure can be displayed as a meaningful time, but nothing more than that is needed.



Two types of timing function are available if the `time` module is imported into Python. The `time.clock()` function seems to be the preferred option, but when I tried it with a Raspberry Pi it provided some odd results, and only seemed to provide a resolution of one second. The `time.time()` function is the alternative, but has the drawback of being alterable by the operating system and application programs. This means that, in theory, it could be altered by other software while it is being used for interval timing by your own application program. In practice, this is unlikely to occur though. The values returned by this function are in seconds, but the resolution is much higher, with values that go to several decimal places. It is unlikely that the accuracy and resolution in real-world timing applications actually gives the microsecond accuracy that the return values imply, but using this function as a millisecond timer seems reasonable.

Reaction timer

As an initial experiment, I used the circuit of Fig.1 and the software of Listing 1 to make a Raspberry Pi act as a simple reaction timer. The hardware just consists of an LED (D1) and series current-limiting resistor (R1) that are driven from pin 26 (GPIO 7) of the GPIO port, and a pushbutton switch (S1) connected from pin 8 (GPIO 14) to the 0V. The basic idea is to have the LED switch on a few seconds after the program is run, and a reading is taken from the timer at this point. The person being tested then has to operate the pushbutton switch as soon as possible. This takes pin 8 low, which is used to indicate to the program that the second reading should be taken. The program then does some simple mathematics and displays the reaction time on the screen.

The initial part of the program does the usual setting up, with the required additional modules being imported, and the mode for the GPIO port being set. Pin 8 of the GPIO port is set as an input with an internal pull-up resistor, and pin 26 is set as an output. The next two lines provide a delay before pin 26 is set high and the LED is switched on. A `time.sleep()` instruction could be used to provide a fixed delay of (say) five seconds, but it is better to use a random delay. With a fixed delay the user will soon start to anticipate the LED switching on, and will produce unrealistically low reaction times.

With a random time it is not possible to anticipate the LED switching on, and valid times will be produced. The `random.randint` function is used to generate an integer from 1 to 8 inclusive, and this value is then used in the `time.sleep` instruction to give a delay in the range 1 to 8 seconds. It takes a couple of seconds or so for the program to load and start working, so the actual delay between the program being run and the LED switching on is between about 3 and 11 seconds.

After the LED has been switched on, the timer is read and the returned value is stored in a variable called `start`. The program then uses the interrupt method to monitor pin 8 of the GPIO port, and provide a hold-off until a transition is detected. Operating the pushbutton switch provides a high-to-low transition, but the program will actually detect a change of either type. The interrupt method is well suited to an application of this type because it should ensure that the transition on the input line is detected and responded to very rapidly. Another reading from the timer is taken once a transition has been detected, and the result is placed in the variable called `end`. The value obtained by deducting `start` from `end` is then printed on the screen, and pin 26 is set low so that the LED is switched off.

Listing 1: Reaction timer

```
import RPi.GPIO as GPIO
import time
import random
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)
GPIO.setup(8, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(26, GPIO.OUT)
delay = random.randint(1,8)
time.sleep(delay)
GPIO.output(26,GPIO.HIGH)
start = time.time()
GPIO.wait_for_edge(8, GPIO.BOTH)
end = time.time()
print (end - start)
GPIO.output(26,GPIO.LOW)
GPIO.cleanup()
print ("Finished")
```

Time it

There are other facilities in Python for timing things, and the `timeit` function is one that is worthy of investigation. When used in the default mode it will use the best timing facility available on the particular platform in use. This will not necessarily be different to the method used by the `time.time()` function, but when using the `timeit` method you should be assured of the best possible results that the hardware and operating system can provide.

The program of Listing 2 is for an alternative version of the reaction timer that uses the `timeit` function. It uses the same hardware as the original version, and operates in the same basic fashion. As before, the initial part of the program imports the necessary modules. It should be noted that the `time` module is still required, since it provides the `sleep()` function. Also as before, the two readings returned from the timer are placed in variables `start` and `end`, but the mathematical processing is a bit different in this case.

With the original method the time is given in seconds, to half a dozen or more decimal places. This is a slightly clumsy way of doing things, given that the reaction time will usually be well under one second, and nothing beyond millisecond accuracy is required. The value obtained by deducting `start` from `end` is therefore processed to produce a reading in milliseconds with figures to the right of the decimal point removed. First the value is multiplied by 1000 to convert it from seconds to milliseconds, and then it is placed in an integer variable to remove the unwanted figures after the decimal point. This value is then printed on the screen.

Listing 2: Reaction timer 2

```
import RPi.GPIO as GPIO
import timeit
import time
import random
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)
GPIO.setup(8, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(26, GPIO.OUT)
delay = random.randint(1,8)
time.sleep(delay)
GPIO.output(26,GPIO.HIGH)
start = timeit.default_timer()
GPIO.wait_for_edge(8, GPIO.BOTH)
end = timeit.default_timer()
secs = end - start
millisec = secs * 1000
millisec = int(millisec)
print (millisec, "milliseconds")
GPIO.output(26,GPIO.LOW)
GPIO.cleanup()
print ("Finished")
```

Most people will obtain reaction times of around 200 to 350 milliseconds. However, substantially longer times can be expected if you are tired or have had a few drinks.

Interval timer

The reaction timer hardware and software is easily modified to provide interval timing, where the start and finish points are activated using separate sensors. The modified circuit of Fig.2 is used. This is the same as before apart from the addition of an extra pushbutton switch (PB2) that can be used to pull pin 24 of the GPIO port (GPIO 8) to ground. This switch is used to indicate the start of the interval, and PB1 is used to indicate the end point. Pushbutton switches are useful when experimenting with this type of thing, but in a real-world application it is more likely that micro-switches, reed switches, or electronic sensors of some kind would be used instead. LED D1 is switched on during the timing interval, and is useful for testing purposes as it shows whether the system is being triggered correctly.

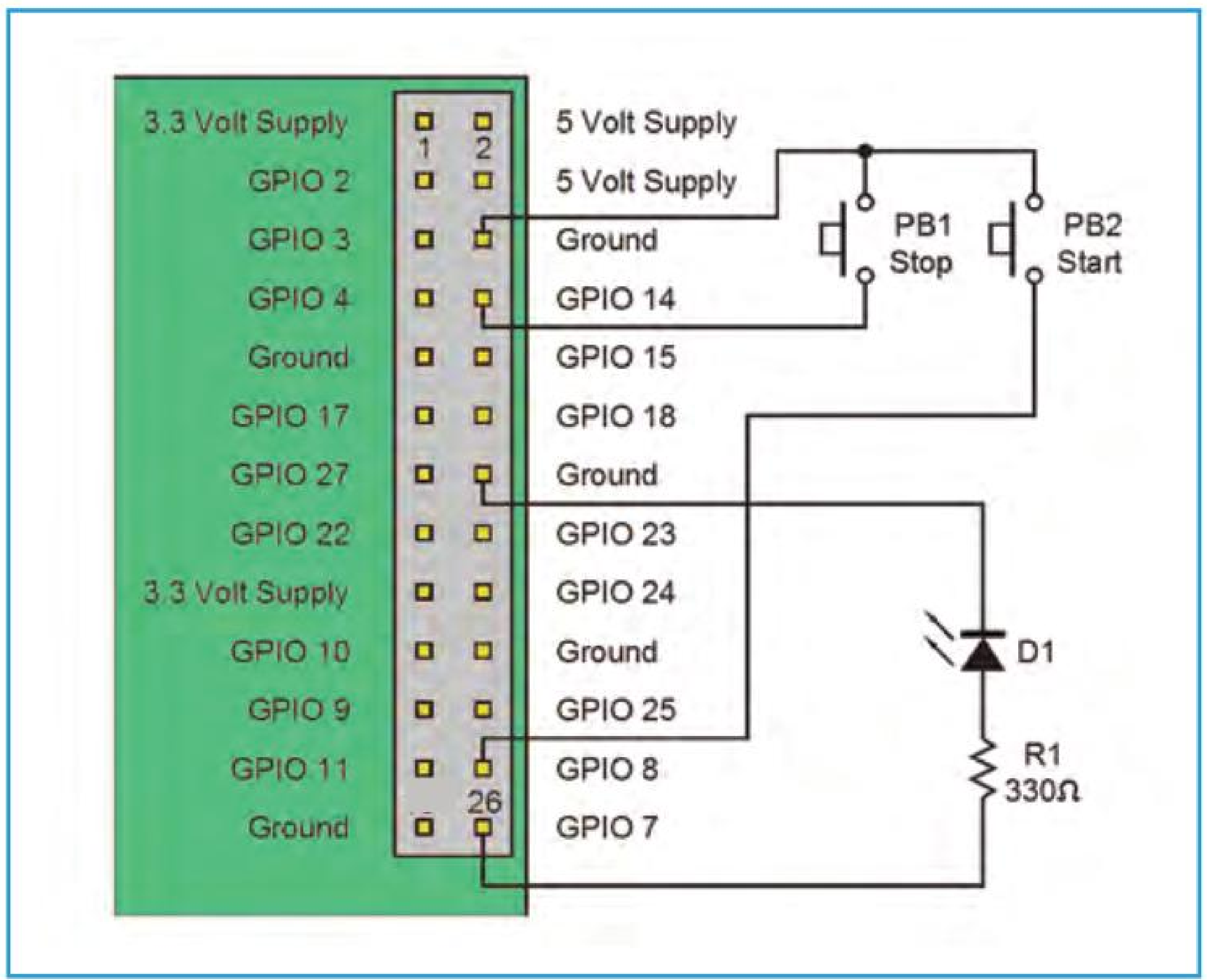


Fig.2. The circuit for the interval timer. In a real-world application the two pushbutton switches would probably be replaced with reed or micro-switches, or electronic sensors of some sort

Listing 3: Interval timer

```
import RPi.GPIO as GPIO
import timeit
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)
GPIO.setup(8, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(24, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(26, GPIO.OUT)
GPIO.wait_for_edge(24, GPIO.BOTH)
start = timeit.default_timer()
GPIO.output(26,GPIO.HIGH)
GPIO.wait_for_edge(8, GPIO.BOTH)
end = timeit.default_timer()
secs = end - start
millisec = secs * 1000
millisec = int(millisec)
secs = millisec/1000
print (secs, "seconds")
GPIO.output(26,GPIO.LOW)
GPIO.cleanup()
print ("Finished")
```

It would be possible to use a single input to monitor the start and stop sensors, but there is a definite advantage in using separate inputs, especially when using mechanical switches to activate the system. Mechanical switches, including the micro and reed varieties, do not switch cleanly and tend to suffer from so-called ‘contact bounce’. In other words, as the switch opens or closes it tends to produce one or more brief pulses rather than the required single transition. Unless steps are taken to deal with this problem it can result in the start indication being followed almost immediately by a stop signal due to contact bounce. This cannot happen when using separate inputs, because the program will only respond to the initial transition on each input.

Listing 3 shows the modified program for interval timing. There is no need to import the `time` module since none of its facilities are required for this program. The initial part of the program otherwise sets things up much as before, but with pin 24 of the GPIO port additionally being set as an input with an internal pull-up resistor. The program waits for a transition on this input, reads the timer, and then switches on the LED. A further hold-off is then provided until a transition is detected on pin 8 of the GPIO port, another reading is taken from the timer, and the LED is switched off.

The timed interval will not necessarily be less than a second in this case, and some additional processing of the raw times is used in order to give a reading in seconds with millisecond resolution. Of course, with suitable processing the time can be displayed in minutes and seconds, hours, minutes and seconds, or whatever is appropriate for a given application.

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CIRCUIT SURGERY

REGULAR CLINIC BY IAN BELL

Selecting the right op amp

RECENTLY user ***741*** posted a question about op amp selection on the *EPE Chat Zone* forum:.

I'm after a fairly fast (say 5MHz) op-amp able to operate with about 15V supply potential from V_{dd} *to* V_{ss} *without emitting smoke. It should be pretty much rail-to-rail I/O (also, low bias plus high PSRR would be nice). I came across the OPA1652 on Farnell's site. I'm guessing the tag 'audio' means 'particularly suitable for audio'... Anything I should be wary of in non-audio applications?*

The forum discussion which followed went into some more detail about the op amp characteristics that ***741*** needed, but we will not be looking at these specifics here. Instead, this month we will address the more general issue highlighted by ***741***'s question, of how you go about selecting the right op amp for your design. Just over a year ago (May to June 2013), we looked at op amp speed and bandwidth in a lot of detail, but here we will take a broader view of op amp characterises. In this article we will define what an ideal op amp should do and describe how to search for a suitable device. Next month, we will look at the implications of a wide range of op amp characteristics.

Minimum specification

The range of circuits that can be designed using op amps, and the number of op amps available, is so vast that no single device is 'the best', and for most applications (even demanding ones) a number of devices from various manufacturers will be appropriate. To select an op amp for a particular application you need to know what the circuit and hence the op amp needs to achieve; this will give you a minimum specification for the device. Where necessary, numerical specifications can be calculated, in other cases it may be sufficient to know that an op amp should be well specified in a particular area. To do this you need an appreciation of what all the specifications mean and what impact they might have on circuit performance.

Looking at the datasheet for an op amp will reveal a large list of parameters, some of which will be more immediately obvious to inexperienced designers than others. Noise and precision (accuracy of DC amplification) are examples of characteristics which might map reasonably directly to particular application requirements, but not all op amp specifications are so straightforward, particularly for novices. For example, limitations due to slew rate and common-mode input range may catch you unawares (we will explain these in more detail next month).

For some applications, choice of op amp will not be very critical (these applications often suit 'general purpose' op amps). However, in other cases choice of op amp can make the difference between a circuit functioning or not. Many years ago the author took over work on a partly developed prototype power control system for a CO_2 laser. The existing laser output measurement circuit used a general purpose op amp which was simply not up to the job. The power measurement worked fine some of the time, but on other occasions would not do anything. The problem was due to the high offset voltages, and more specifically the change in offset with time and temperature. The circuit could have been built successfully using high precision op amps but was replaced with one using peak measurement chips, which did a great job.

The above example illustrates a couple of points. First, it is the imperfections in 'real' op amps (as opposed to the fundamental behaviour of 'ideal' ones) that tend to cause problems, so understanding these and their impact will help you avoid devices that are unsuitable. Second, there are situations where specialist chips other than op amps are the best option. The above case was one example, another would be a sample and hold circuit – you can build one using an op amp, but you will usually get better performance from a sample and hold chip, where of course some extra bits of circuitry are already included. Comparators are another case – all op amps can be used as comparators, but it is often better to use chips optimised for this purpose.

Ideal device

Before looking at op amp specifications in detail we need to define what an op amp is and how an ideal device would behave. An op amp is a high-gain, direct-coupled amplifier, its symbol is shown in Fig.1. The term 'direct-coupled' means that the inputs and internal stages are connected directly, not via coupling capacitors. This enables the op amp to amplify dc and very low frequency signals. It has two inputs: the inverting and non-inverting inputs, and one output.

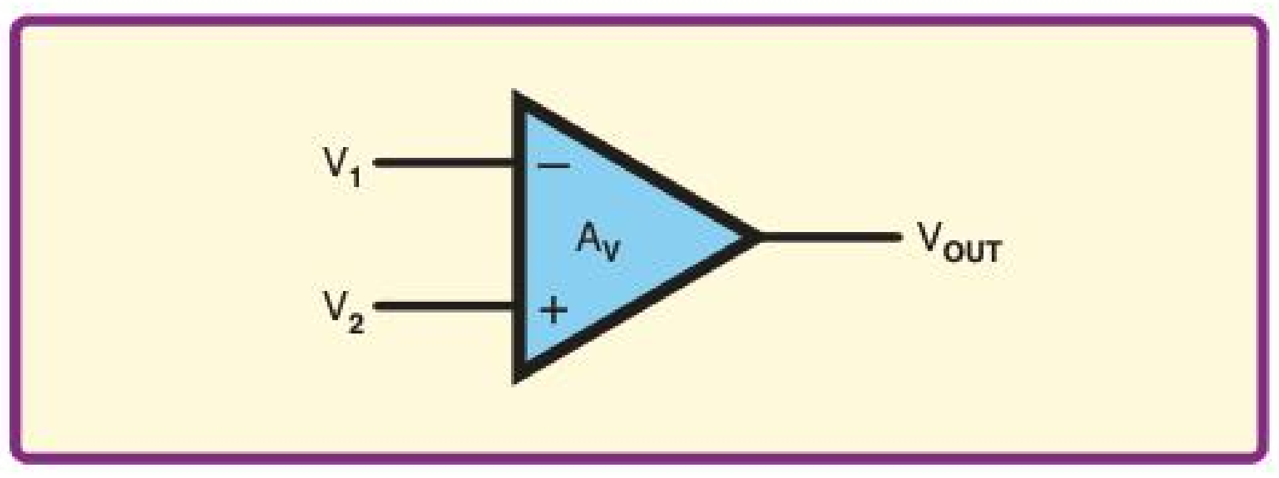


Fig.1. Op amp symbol

The output voltage of an op amp is given by $V_{out} = A_v(V_2 - V_1)$. Where A_v is the open-loop voltage gain, V_2 is the non-inverting input voltage and V_1 is the inverting input voltage. Open-loop gain refers to the gain of the op amp itself, without any feedback circuitry and is really the only characteristic of an ideal device – just about everything else in a real device's specification is about imperfections and limitations. The gain of ideal op amps is often assumed to tend to infinity.

An op amp amplifies the difference in voltage between its two inputs. The equation $V_{out} = A_v(V_2 - V_1)$ always holds for an ideal device, but in reality is only valid for a small range of $(V_2 - V_1)$. The value of A_v is typically from tens of thousands to millions (at least at low frequencies), so V_2 to V_1 differences of microvolts to millvolts produce outputs in the range of volts. The value of V_{out} cannot exceed the supply voltage and may be limited lower than this. If $A_v(V_2 - V_1)$ is above the maximum output voltage the op amp is said to be saturated. The op amp's input-output relationship is illustrated in Fig.2.

Op amps are almost always used with negative feedback, which results in a gain for the circuit that is typically very much smaller than that of the op amp itself. The voltage between the op amp's inputs will always be very small (as indicated above) unless it is saturated, even if the circuit inputs are at a much higher level. Comparators use open loop op amps or positive feedback, but as already indicated it is usually better to use specific comparator chips rather than op amps for this purpose.

Op amps often have two power supplies, one at a positive voltage

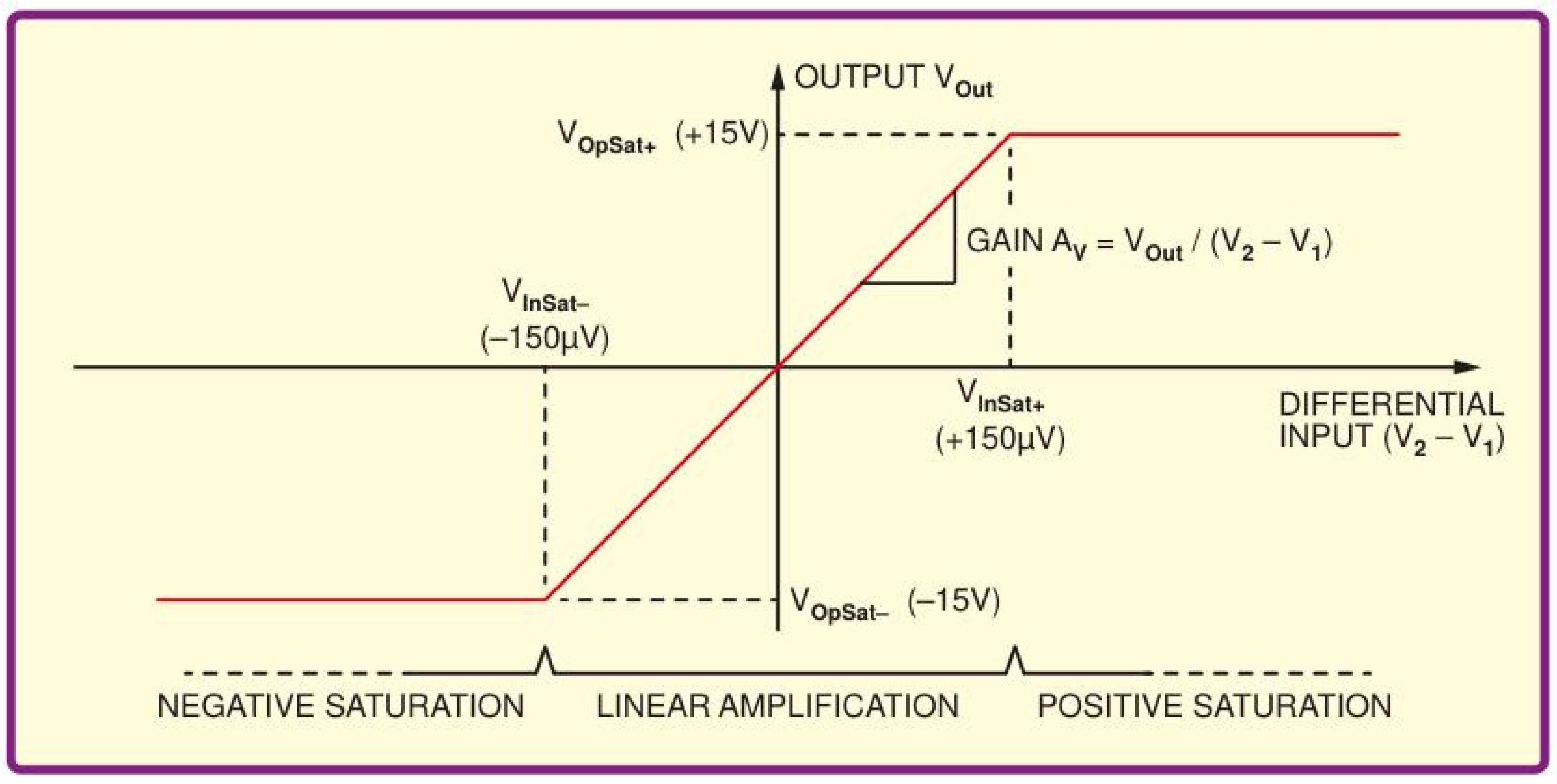


Fig.2. A graph showing the relationship between op amp differential input voltage and output voltage. Saturation occurs when any increase in the magnitude of the differential input does not result in further increase in output voltage magnitude. The values shown are an example for an op amp with a gain of 100,000 and maximum output voltage of ±15V. The gain of the op amp is equal to the slope of the graph between the saturation points

with respect to ground and the other at the same magnitude negative with respect to ground; this enables it to handle both positive and negative input and output voltages. However, many op amps targeted at 'single supply' operation are also available. The power supply connections are not always shown on schematics.

Offset

The output of an ideal op amp depends on the difference between V_2 and V_1 and nothing else. First, this means that if both inputs are at the same voltage an ideal op amp will always output zero volts, but a real device is likely to give a non-zero output (known as an offset). Second, if V_2 and V_1 change from, say, 50µV and –50µ V to 10.00005V and 9.99995V the output will not change because the difference ($V_2 - V_1$) is still 100µV. What has changed here is called the common-mode input voltage. In the first case it is 0V and in the second it is 10V. For an ideal device the common-mode input voltage does not affect the output at all, and there is no limit to its value. Similarly, changes in power supply voltage should have no effect on the output voltage, but in practice they do.

For an ideal op amp there are no limits on input voltages, supply voltage and current, output current, power dissipation etc. Obviously real devices do have such limits, and exceeding them may destroy the device or cause it to enter a limiting mode (limiting is common for output current).

The inputs of an ideal op amp have infinite resistance (or impedance), consequently absolutely no current flows into these inputs. This is not true for real for devices where some current flows into the inputs to provide bias to the transistors in the input stage. Op amps with field-effect transistors (FETs) in their input stage tend to have lower input currents.

Bandwidth

An ideal op amp can amplify signals of any frequency and has zero delay from input to output. For real devices the delay is not zero, this, in combination with negative feedback, means that circuits will be unstable unless the open loop gain is reduced at high frequencies. The theory behind this is beyond the scope of this article, but in practice it means that op amps are designed so that their gain decreases with increasing frequency – this is called frequency compensation. Consequently, real op amps have a finite bandwidth. A typical op amp open-loop frequency response curve is shown in Fig.3. We have covered this in more depth in previous articles.

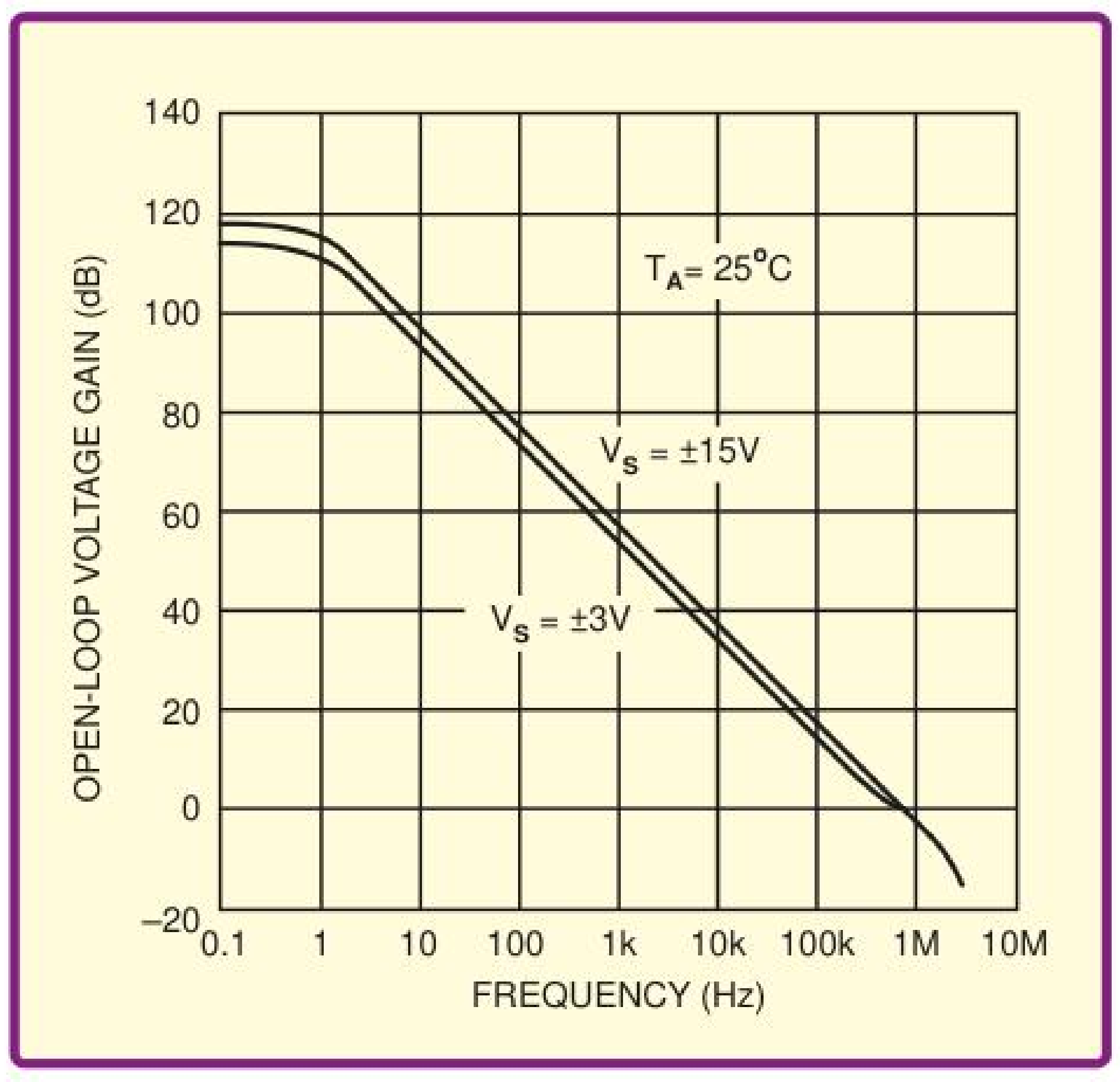


Fig.3. Typical op amp open-loop frequency response (this is for the LT1002, from the Linear Technology datasheet)

An ideal op amp will be able to reproduce a waveform of any shape at its output. However, real devices will fail to do this if the rate of change of the signal (slew rate) is too high, or the output current limit or maximum output voltage is exceeded. Deviation of an output signal from its required shape is referred to as distortion. The limiting conditions of speed and amplitude just described may cause extreme distortion, but even when an op amp is within these limits it may also cause some distortion of the signal.

The above discussion gives us some idea of imperfections and limitations we might expect in a real device. Chip designers strive to make op amps with high performance, but as with all engineering there are trade-offs, so that making a device excel in one area will tend to mean lower performance in another. An example trade-off is between speed and precision – high speed, high frequency op amps do not tend to have very good dc accuracy and high precision op amps are often relatively slow and have lower bandwidths.

Once you have some idea of what you are looking for, the search for a suitable device can begin. It is generally best not to use Google or other general search engines because this will tend to find a lot general information about op amps rather than finding specific devices. An exception to this might be if you are looking for recommendations in a niche area where they may be specialist discussion forums (eg, DIY audio).

In general, the best places to start looking are large component suppliers and the manufacturers of the devices themselves. Components suppliers include:

Farnell (**www.farnell.com**),
RS (**www.rs-components.com**)
Digikey (**www.digikey.com**)

Manufactures of wide ranges of op amps include:

Analogue Devices (**www.analog.com**)
Linear Technology (**www.linear.com**)
ON Semiconductor (**www.onsemi.com**)
STMicroelectronics (**www.st.com**)
Texas Instruments (**www.ti.com**)

Searching on a supplier site will find devices from a wide range of manufacturers, but may not include all the devices from each manufacturer. Obviously a manufacture's sites will only list their own op amps.

Something that may help is that manufacturers often group their op amps into types suited to different kinds of application, and these can help narrow down your search. This is exactly what ***741*** is referring to when he says that the OPA1652 is tagged with the word 'audio'. Typical categories may include the following.

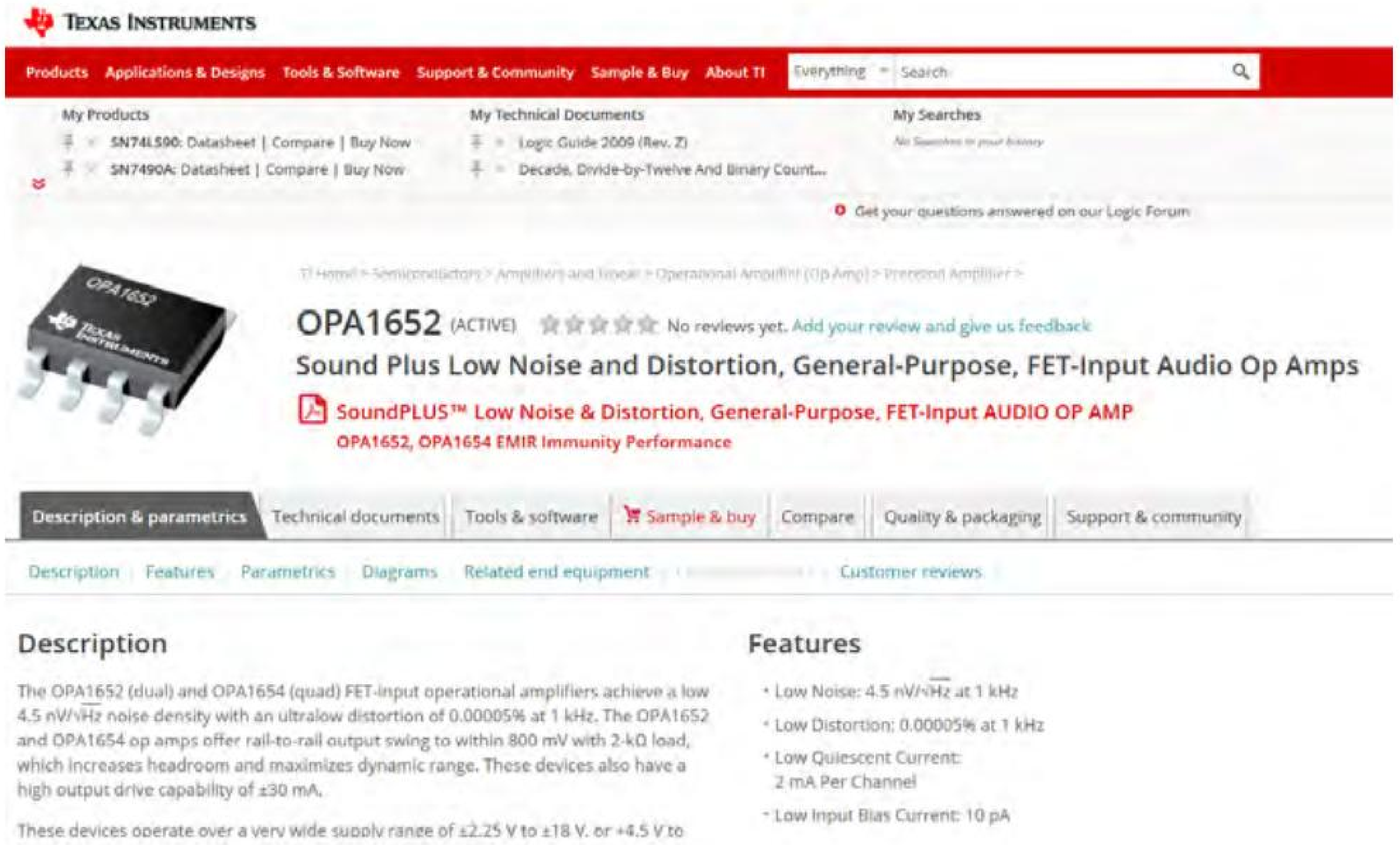
- **General-purpose** – suitable for a wide range of applications requiring moderate amplifier performance. These are typically lower cost but do not excel in any particular area.
- **Low noise** – guaranteed very low noise for applications such as sensitive measurement and signal processing (including audio) where noise from the op amp must be within known bounds.
- **Low-power/micopower** – suitable for use in systems, such as mobile equipment, where power consumption is critical.
- **Wideband/high speed** – suitable for applications such as pulse circuits and video where accurate reproduction of complex high frequency signals is required.
- **Low drift/high precision** – amplifiers with minimal offset voltage, and where accuracy is preserved over a wide temperature range,

- **Low bias/high impedance** – op amps with very low input bias currents for use in application such as buffer circuits, processing of signals from high impedance sensors, low level current measurement and in circuits with large external resistors.
- **Rail-to-rail** – op amps that can process signals very close to the supply voltage at their inputs, output or both.
- **High voltage/high power** – op amps able to operate at higher supply voltages and/or output currents than most other devices. Op amps with high current output stages are capable of driving low impedance loads.
- **Audio** – op amps with low noise, low distortion and other characteristics suitable for high quality audio signal processing.

Some op amps may belong to more than one of these categories, and different manufactures may use different terminology. Other categorisation may include usage domains such as automotive, industrial and military. These are based on factors as such as operating temperature range, quality levels and conformance to certain standards. This is not usually of much interest to amateur designers.

Selection tables

Supplier and manufacturer websites often provide interactive selection tables to help you find the most suitable devices. To use these effectively you have to have some idea of which op amp parameters are most important and what range of values are appropriate. Fig.4 shows part of a typical parametric selection table from a manufacturer's website (Texas Instruments in this case). Note that categories similar to those listed above can be used here as part of the selection process (in the 'Subfamily' column).



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Sound Plus Low Noise and Distortion, General-Purpose, FET-Input Audio Op Amps

SoundPLUS™ Low Noise & Distortion, General-Purpose, FET-Input AUDIO OP AMP
OPA1652, OPA1654 EMIR Immunity Performance

Description

The OPA1652 (dual) and OPA1654 (quad) FET-input operational amplifiers achieve a low 4.5 nV/√Hz noise density with an ultralow distortion of 0.00005% at 1 kHz. The OPA1652 and OPA1654 op amps offer rail-to-rail output swing to within 800 mV with 2-kΩ load, which increases headroom and maximizes dynamic range. These devices also have a high output drive capability of ±30 mA.

These devices operate over a very wide supply range of ±2.25 V to ±18 V, or +4.5 V to

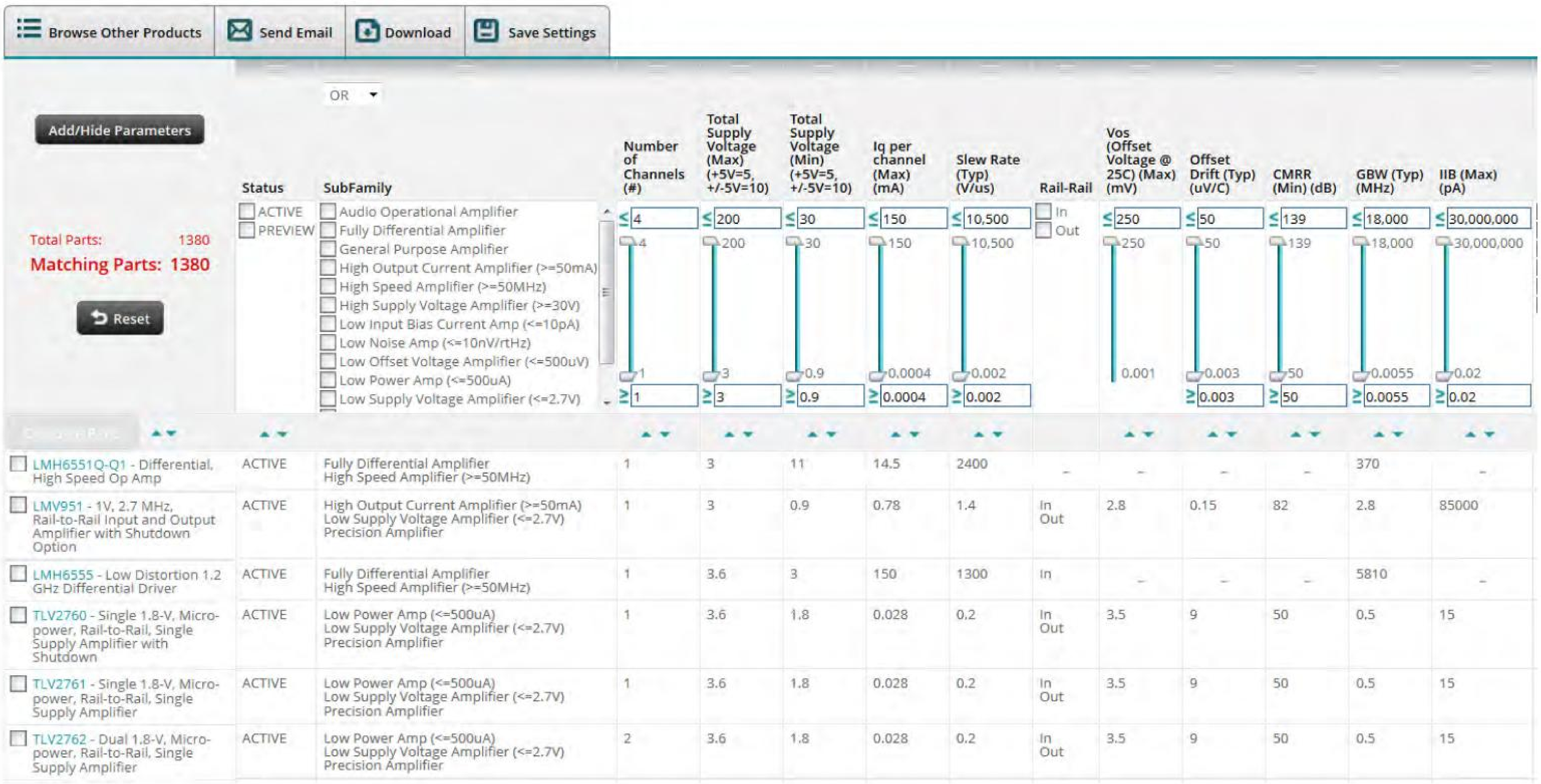
Features

- Low Noise: 4.5 nV/√Hz at 1 kHz
- Low Distortion: 0.00005% at 1 kHz
- Low Quiescent Current: 2 mA Per Channel
- Low Input Bias Current: 10 pA

Fig.5. Part of the overview page from the OPA1652 from Texas Instruments. This page provides access to a variety of resources such as the datasheet, application notes and simulation models

Once you have selected a small set of potential devices via the selection table you can visit the overview pages for devices of interest. Part of the manufacturer's page for the OPA1652 (mentioned by ***741***) is shown in Fig.5. On a supplier site this will provide technical details plus prices and stock levels. On a manufacturer's site you will usually find more technical resources, in addition to an overview of the device and its key specifications. Some supplier sites will also link through to the manufacturer's overview page. You may find overview pages for devices which are obsolete (no longer in active production) or soon to be discontinued. These should be avoided in new designs. The page may list suitable alternative in-production devices.

One of key resources for any device is the datasheet. This provides full details of the characteristics and specifications. If the overview pages indicate that the device might be a suitable one for your design then the datasheet should be checked to make sure that all the details are right. Other resources may include simulation models, other technical articles such as application notes, online tools for simulation and design assistance and models for use with PCB design tools.



Total Parts: 1380
Matching Parts: 1380

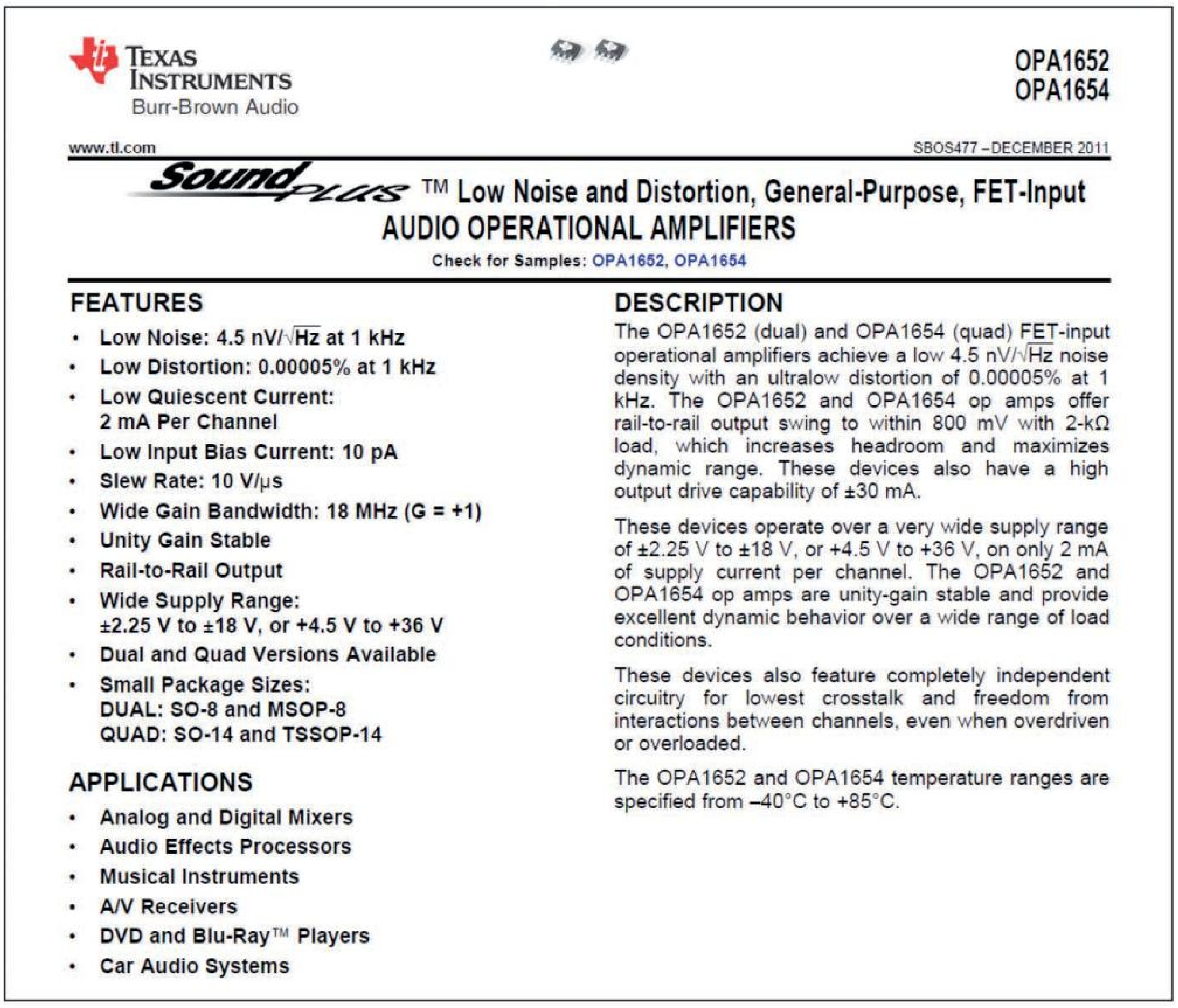
Status
☐ ACTIVE
☐ PREVIEW

SubFamily
☐ Audio Operational Amplifier
☐ Fully Differential Amplifier
☐ General Purpose Amplifier
☐ High Output Current Amplifier (>=50mA)
☐ High Speed Amplifier (>=50MHz)
☐ High Supply Voltage Amplifier (>=30V)
☐ Low Input Bias Current Amp (<=10pA)
☐ Low Noise Amp (<=10nV/rtHz)
☐ Low Offset Voltage Amplifier (<=500uV)
☐ Low Power Amp (<=500uA)
☐ Low Supply Voltage Amplifier (<=2.7V)

Rail-Rail: ☐ In ☐ Out

	Status	SubFamily	Number of Channels (#)	Total Supply Voltage (Max) (+5V=5, +/-5V=10)	Total Supply Voltage (Min) (+5V=5, +/-5V=10)	Iq per channel (Max) (mA)	Slew Rate (Typ) (V/us)	Rail-Rail	Vos (Offset Voltage @ 25C) (Max) (mV)	Offset Drift (Typ) (uV/C)	CMRR (Min) (dB)	GBW (Typ) (MHz)	IIB (Max) (pA)
			≤ 4	≤ 200	≤ 30	≤ 150	≤ 10,500		≤ 250	≤ 50	≤ 139	≤ 18,000	≤ 30,000,000
			4	200	30	150	10,500		250	50	139	18,000	30,000,000
			1	3	0.9	0.0004	0.002		0.001	0.003	50	0.0055	0.02
			≥ 1	≥ 3	≥ 0.9	≥ 0.0004	≥ 0.002			≥ 0.003	≥ 50	≥ 0.0055	≥ 0.02
☐ LMH6551Q-Q1 - Differential, High Speed Op Amp	ACTIVE	Fully Differential Amplifier High Speed Amplifier (>=50MHz)	1	3	11	14.5	2400	_	_	_	_	370	_
☐ LMV951 - 1V, 2.7 MHz, Rail-to-Rail Input and Output Amplifier with Shutdown Option	ACTIVE	High Output Current Amplifier (>=50mA) Low Supply Voltage Amplifier (<=2.7V) Precision Amplifier	1	3	0.9	0.78	1.4	In Out	2.8	0.15	82	2.8	85000
☐ LMH6555 - Low Distortion 1.2 GHz Differential Driver	ACTIVE	Fully Differential Amplifier High Speed Amplifier (>=50MHz)	1	3.6	3	150	1300	In	_	_	_	5810	_
☐ TLV2760 - Single 1.8-V, Micro-power, Rail-to-Rail, Single Supply Amplifier with Shutdown	ACTIVE	Low Power Amp (<=500uA) Low Supply Voltage Amplifier (<=2.7V) Precision Amplifier	1	3.6	1.8	0.028	0.2	In Out	3.5	9	50	0.5	15
☐ TLV2761 - Single 1.8-V, Micro-power, Rail-to-Rail, Single Supply Amplifier	ACTIVE	Low Power Amp (<=500uA) Low Supply Voltage Amplifier (<=2.7V) Precision Amplifier	1	3.6	1.8	0.028	0.2	In Out	3.5	9	50	0.5	15
☐ TLV2762 - Dual 1.8-V, Micro-power, Rail-to-Rail, Single Supply Amplifier	ACTIVE	Low Power Amp (<=500uA) Low Supply Voltage Amplifier (<=2.7V) Precision Amplifier	2	3.6	1.8	0.028	0.2	In Out	3.5	9	50	0.5	15

Fig.4. Op amp search table from the Texas Instrumnets website. Setting the parameter requirements and sort direction in each colmun helps you find the rigth device. Other manufactures use similar tables



TEXAS INSTRUMENTS
Burr-Brown Audio

OPA1652
OPA1654

www.ti.com

SBOS477 – DECEMBER 2011

SoundPlus™ Low Noise and Distortion, General-Purpose, FET-Input AUDIO OPERATIONAL AMPLIFIERS

Check for Samples: OPA1652, OPA1654

FEATURES

- Low Noise: 4.5 nV/√Hz at 1 kHz
- Low Distortion: 0.00005% at 1 kHz
- Low Quiescent Current: 2 mA Per Channel
- Low Input Bias Current: 10 pA
- Slew Rate: 10 V/μs
- Wide Gain Bandwidth: 18 MHz (G = +1)
- Unity Gain Stable
- Rail-to-Rail Output
- Wide Supply Range: ±2.25 V to ±18 V, or +4.5 V to +36 V
- Dual and Quad Versions Available
- Small Package Sizes:
  DUAL: SO-8 and MSOP-8
  QUAD: SO-14 and TSSOP-14

APPLICATIONS

- Analog and Digital Mixers
- Audio Effects Processors
- Musical Instruments
- A/V Receivers
- DVD and Blu-Ray™ Players
- Car Audio Systems

DESCRIPTION

The OPA1652 (dual) and OPA1654 (quad) FET-input operational amplifiers achieve a low 4.5 nV/√Hz noise density with an ultralow distortion of 0.00005% at 1 kHz. The OPA1652 and OPA1654 op amps offer rail-to-rail output swing to within 800 mV with 2-kΩ load, which increases headroom and maximizes dynamic range. These devices also have a high output drive capability of ±30 mA.

These devices operate over a very wide supply range of ±2.25 V to ±18 V, or +4.5 V to +36 V, on only 2 mA of supply current per channel. The OPA1652 and OPA1654 op amps are unity-gain stable and provide excellent dynamic behavior over a wide range of load conditions.

These devices also feature completely independent circuitry for lowest crosstalk and freedom from interactions between channels, even when overdriven or overloaded.

The OPA1652 and OPA1654 temperature ranges are specified from –40°C to +85°C.

Fig.6. First page of the OPA1652 data sheet. This provides an overview similar to the web page. Detailed specification information can be found on subsequent pages

The first page of the datasheet will usually list the 'headline' parameters which highlight the best features of the device (for example see Fig.6, which is for the OPA1652). There will usually be a written description and a list of application areas. The first page will cover similar things to an overview web page and both are effectively part of the marketing of the device. The full details follow in the rest of the datasheet, which is what we be looking at next month.

Returning briefly to ***741***'s question, the slew rate of the OPA1652 may be an issue as he is interested in relatively large amplitude signals at frequencies higher than standard audio. This op amp may not be able to change its output voltage fast enough to reproduce the signals without distortion. The OPA1652's slew rate is stated on both the overview web page (not shown in Fig.5) and on the first page of the data sheet.

ELECTRONICS TEACH-IN 5

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READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

Stereo Compressor project

Dear editor
Thank you very much for publishing this excellent project (*Stereo Compressor*, *EPE* Jan 2013), I built one recently and was thrilled by how well it works. I had been looking for a low-cost compressor project for my music hobby, and all other designs I found were using hard-to-find or very expensive components.

The compression in the *EPE* project is quite 'polite' – you can't go really over the top, but it adds some really nice punch to snares and tightens up kick drums. The compression ratio is fixed at 2:1.

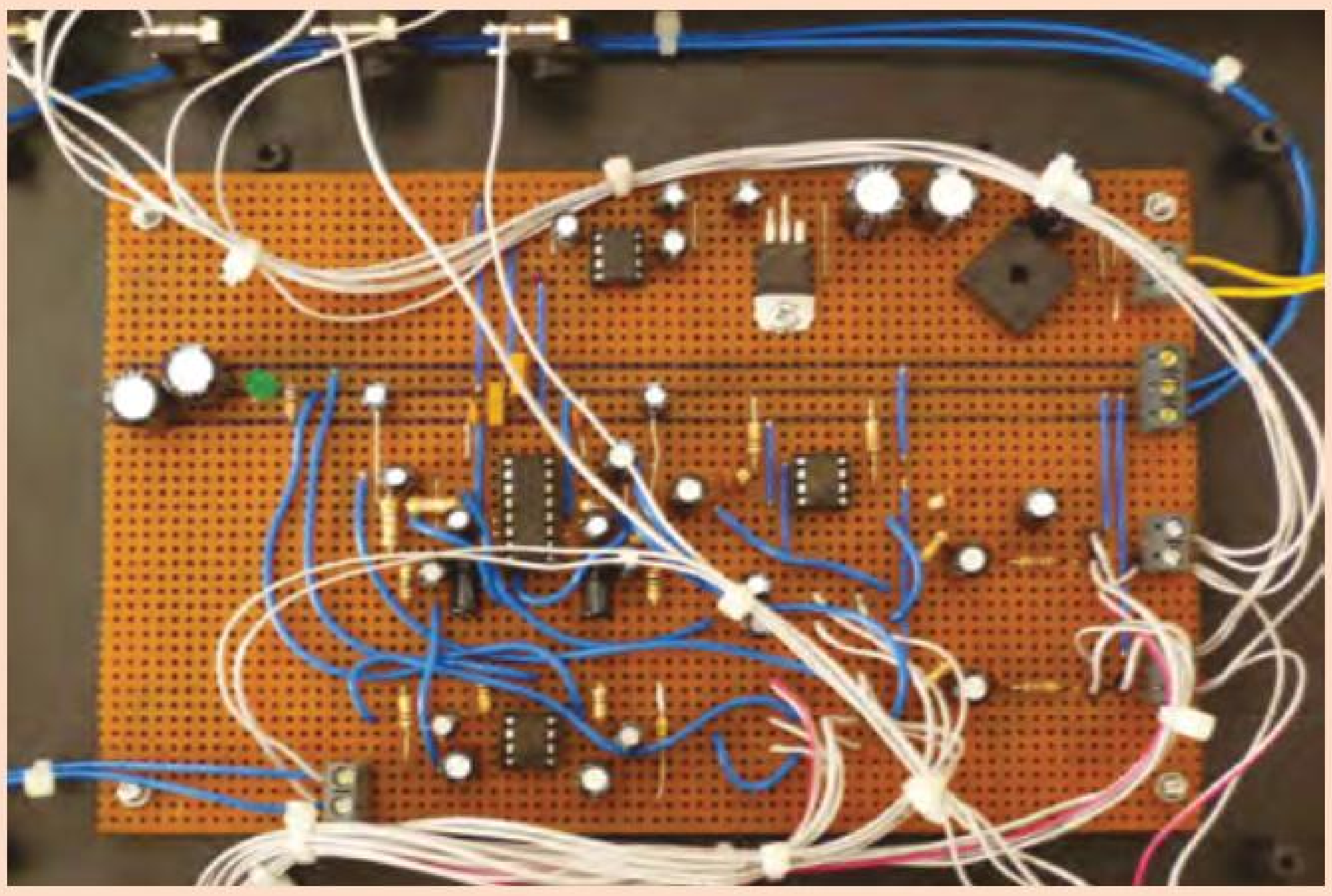


Fig.1. Details of Harry Axten's Veroboard-based construction of the *EPE Stereo Compressor* (January 2013, *EPE*).

I housed the compressor in a 19-inch rack-mount case and added some additional features like a stereo VU meter (LM3914), bypass switch, input trim, together with ¼-inch unbalanced inputs and outputs. I also redesigned the power supply circuitry to provide a split rail ±5V supply from a single +5V rail (using the ICL7660 DC-DC converter IC) – see the schematic for my new power supply.

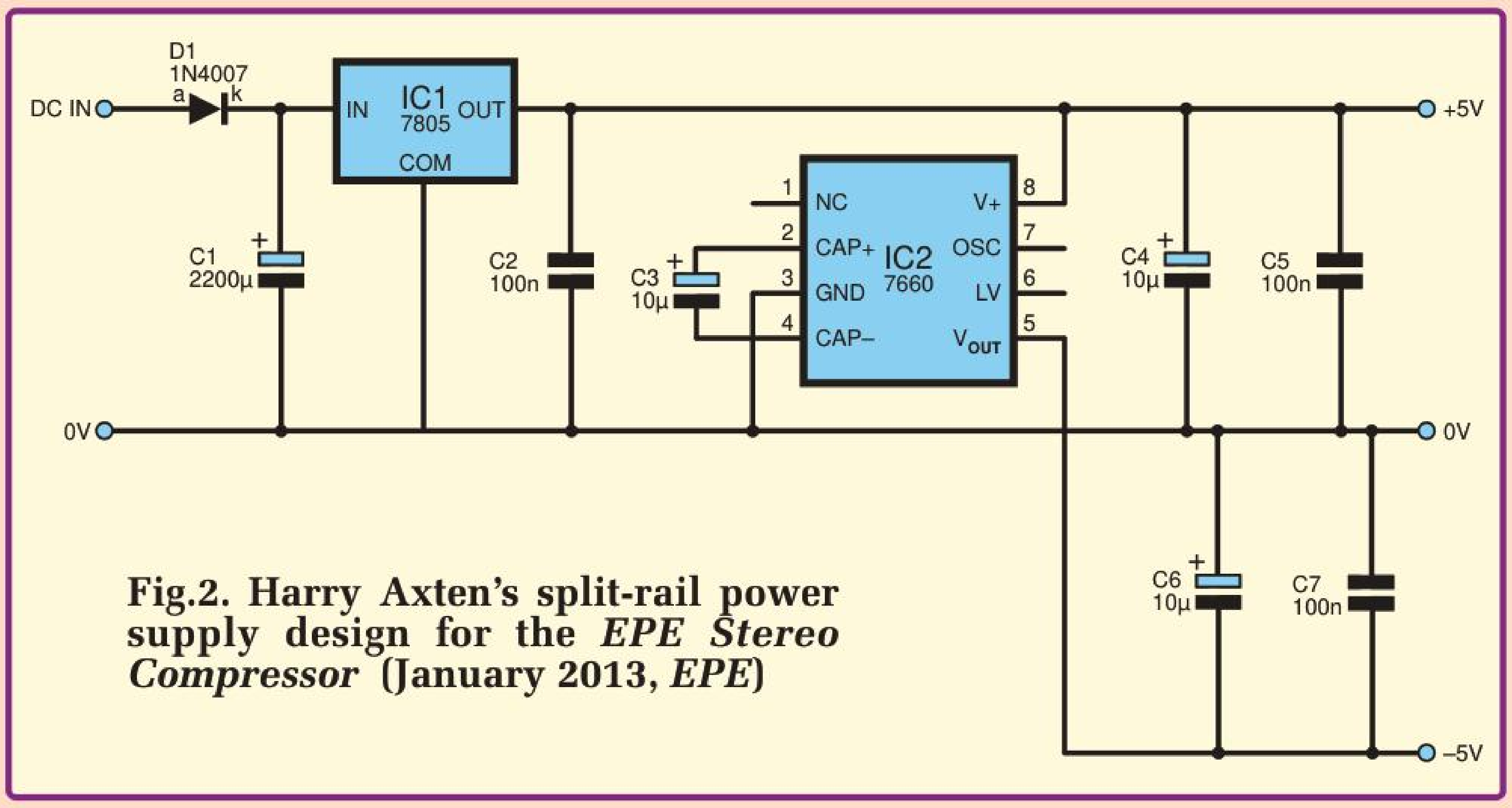
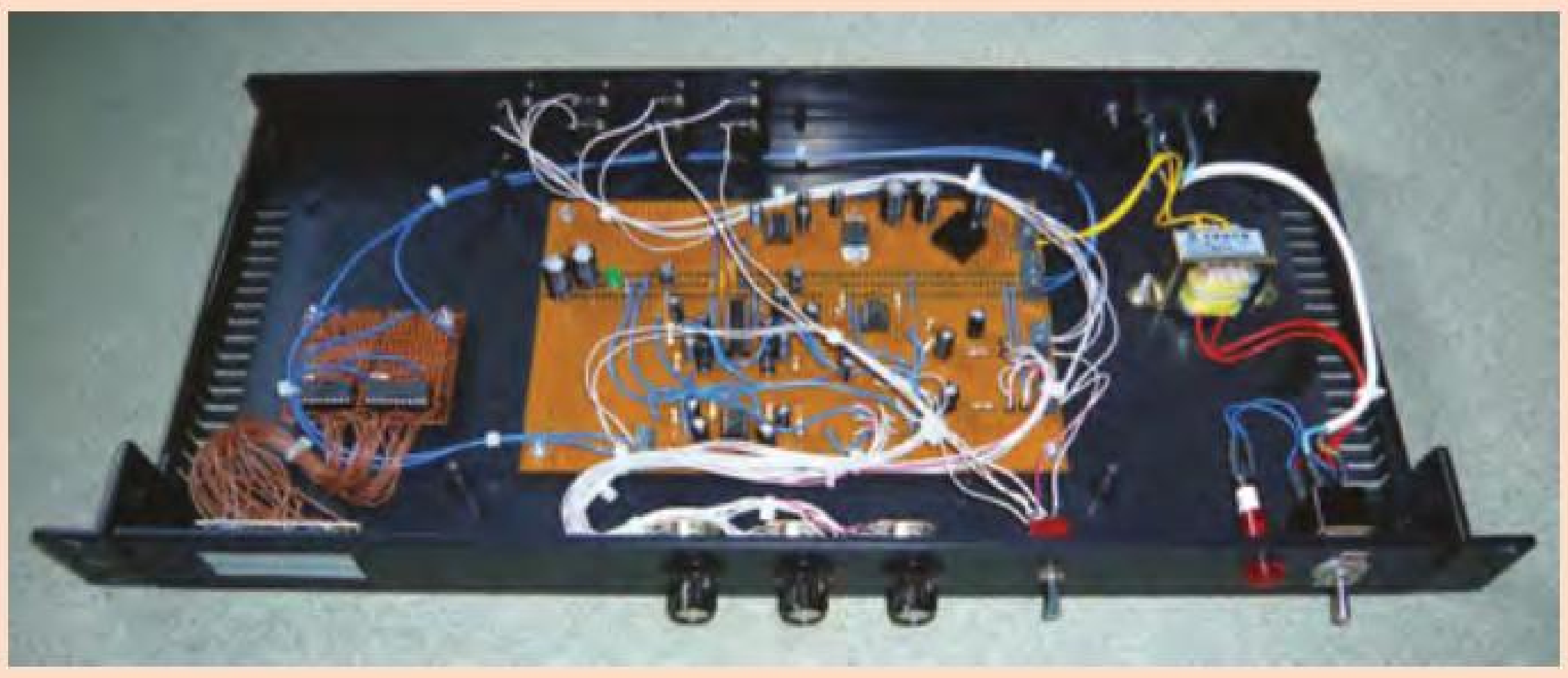
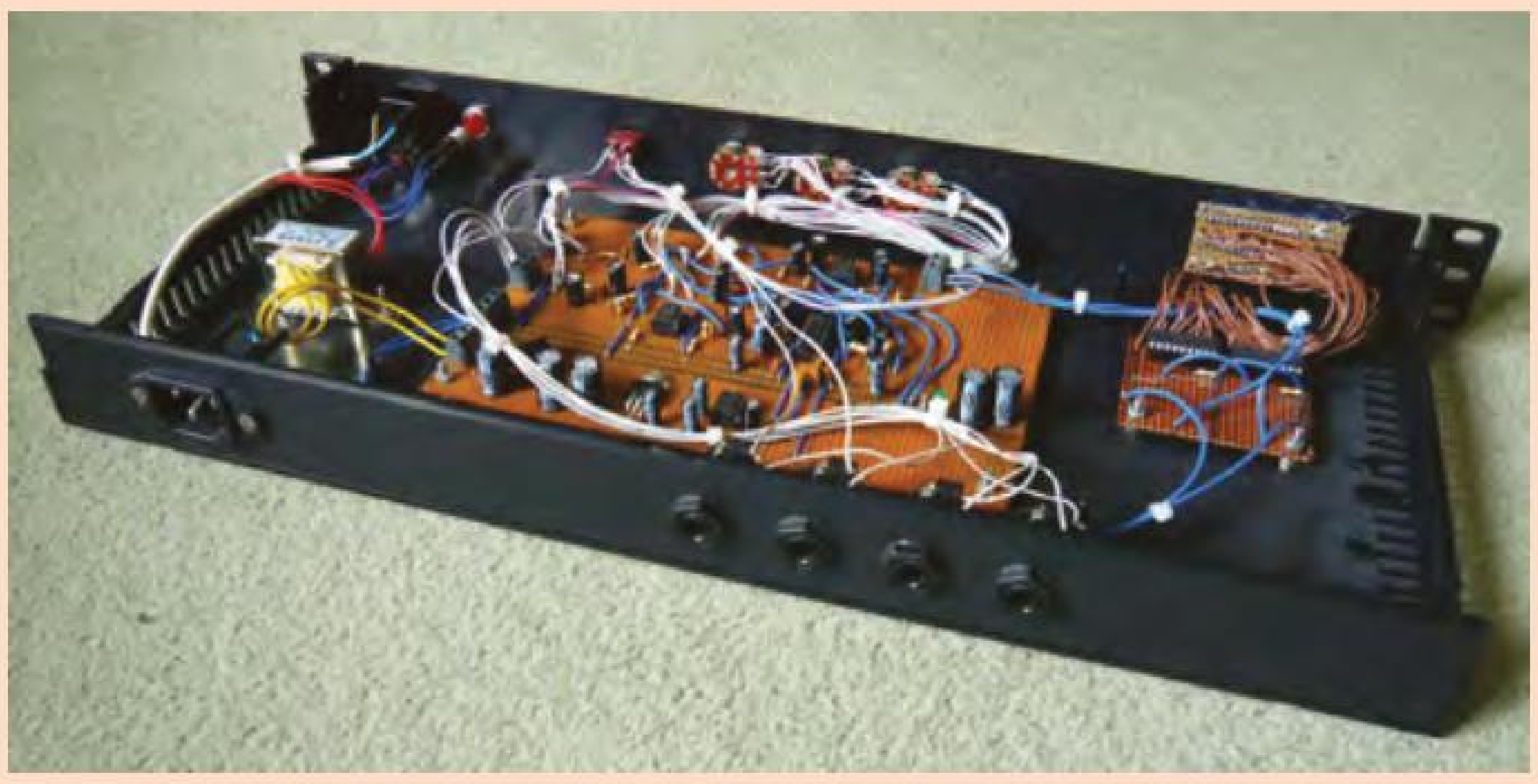


Fig.2. Harry Axten's split-rail power supply design for the *EPE Stereo Compressor* (January 2013, *EPE*)





To keep build costs to a minimum I constructed the circuitry on Veroboard. The total cost for the project including case, switches and ancillaries was less than £35. I couldn't even get a beaten up, broken compressor on eBay for this price, so I am extremely happy.

Despite the slightly messy wiring, there is no hum in the signal. Amazingly, this project worked first time (apart from a crackly potentiometer).

I put together a video to demonstrate how nice this project sounds: **http://youtu.be/EvqzKFCj6fQ**

Thank you again.

Harry Axten, by email

Matt Pulzer replies:

Great result Harry, and thank you very much for sharing the fruits of your labour. Few letters give us more pleasure than those from readers who successfully upgrade or improve our projects. As the YouTube video demonstrates, for £35 you have made a really superb compressor, one that not only sounds great but looks the part too.

Given all the social media opportunities we have these days, I would like to really encourage other readers to share their success this way. It's fun to see projects in the flesh and I hope it will encourage others to take the plunge and build a project.

European colour code chaos

Dear editor

With reference to the imported multi-gang mains socket (*EPE*, April 2014, *News*, page 8), yes, black REALLY IS phase! Watch out, touch what you think is neutral and you could be in for a nasty surprise.

We're in Europe, so, to permit free movement of labour, electricians need to work on a harmonised colour code (introduced April 2006, apparently it's in BS7671). Our old three phases (for fixed installation cables) were red/yellow/blue (with black neutral) but they are now brown/black/grey (with blue neutral). I can't see the logic. To work in another country requires knowledge of the entire local wiring regulations, not just the colour code. Now we have the situation where, probably for decades to come, buildings in the UK could have wiring to two colour schemes at once (there's even an official warning label to stick on the consumer unit when this happens). I predict someone will touch black live and be killed before long.

The photograph of a distribution panel appears to have black phase, white neutral and red protective (earth) conductors. This is exactly the old Swedish specification, they wouldn't have thought anything odd about it if sold there! Apart from the colours, it's not bad – decent bit of labour-intensive point-to-point soldering, rather than the modern trend of spot-welded open bus-bars.

Appears to screw together as well, none of these cheap one-time clips moulded into the casing. The thing on the right, though (switch or circuit breaker I think), is in the neutral. Also, some of the interior wiring might be missing, hard to tell in the photo.

Can't be too careful!

Godfrey Manning G4GLM Edgware, by email

Matt Pulzer replies:

Thank you Godfrey, sound advice and a useful warning. When I was a research engineer I worked with Japanese electrical/electronic engineers. One of them, just a few days into his work in the UK, touched a mains brown wire. His reasoning was that the earth was 'brown' coloured and hence this cable should be safe. Needless to say the poor chap got a nasty jolt – fortunately not a serious one.

We should all tread very cautiously when dealing with foreign colour codes – and never assume we know which cable is earth, neutral or a phase.

Arduino in *EPE*

Dear editor

I do like you excellent recent series on Raspberry Pi. Have you run any good articles/series on the Arduino? – I have just purchased one.

Graham Hunter, by email

Matt Pulzer replies:

Thanks for your enquiry about Arduino. We tend not to cover Arduino that often. We don't have anything against Arduino, it is an excellent product, but there is a limit to how many controller-type devices we can cover properly.

Most of our projects tend to be PIC oriented, and as you know, we are now including Raspberry Pi in EPE*.*

From time to time we will include an Arduino project, but I don't have anything lined up at the moment.

I'm sorry to be the bearer of disappointing news, and hope you continue to enjoy EPE.

Circuit Surgery queries

Dear editor

I am electronics engineering student; I want to know how to write a problem to *EPE* so that my questions could be discussed in *Circuit Surgery*.

Shayaan Mustafa, by email

Matt Pulzer replies:

The Circuit Surgery *author usually picks up ideas from our forum:* ***http://www.chatzones.co.uk***

The magazine does not answer specific questions because of the volume of questions this would inevitably create. However, you can usually find someone in the forum who can help you. It is full of friendly and experienced hobbyists and engineers, so I strongly urge you to visit there.

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Max's Cool Beans

By Max The Magnificent

BADASS display case

In my previous column, I described the circumstances that led me to start work on my *Bodacious Acoustic Diagnostic Astoundingly Superior Spectromatic* (BADASS) display. As you may recall, this little scallywag is going to comprise a 16 × 16 = 256 array of tri-colored LEDs.

The main front panel will be 42 inches wide and 38 inches tall. This is going to be formed from 3/4-inch plywood that is stained to look like antique wood. The display panel itself – along with the small control panel – is going to be made from hardboard that is painted to look like antique brass. The 16 columns of LEDs will be implemented using NeoPixel Strips from Adafruit (**http://bit.ly/1kDOXnd**). A couple of days ago, as I pen these words, I spent a happy weekend in our garage routing out the areas in the plywood for the hardboard panels, along with the vertical slots that will accommodate the LEDs.

The next step will be to drill the 256 holes in the large hardboard panel for the LEDs and the six holes in the small hardboard panel for the momentary push buttons. Also, I'll need to drill the mounting holes that will be used to attach the hardboard panels to the main panel – I'm using mega-cool brass acorn nuts for this purpose (**http://bit.ly/1p5ojZl**).

Each of the LEDs is going to be presented behind an approximately one-inch diameter countersunk brass washer (**http://bit.ly/1hSEwMh**). Furthermore, in the center of each washer will be a clear plastic Fresnel lens (**http://bit.ly/1l1psjG**). Of course, nothing is ever simple – the bodies of the lenses are just a tad too wide, which means I have to drill the holes in the washers a fraction bigger, but that's the way the cookie crumbles. All I can say is that, based on my test piece, the end result is going to look magnificent.

Cabinet refinement

Originally, I was going to create the main wooden cabinet and stain all the wood myself. However, a friend introduced me to a couple of guys who have businesses in the less salubrious backstreets of our downtown area. One of these guys, we'll call him Bob (because that's his name), is an expert at restoring and/or recreating antique furniture; the other, Philip, is a master of stains and polishes and finishes. We sketched out a couple of ideas, and they are going to create the main cabinet for me.

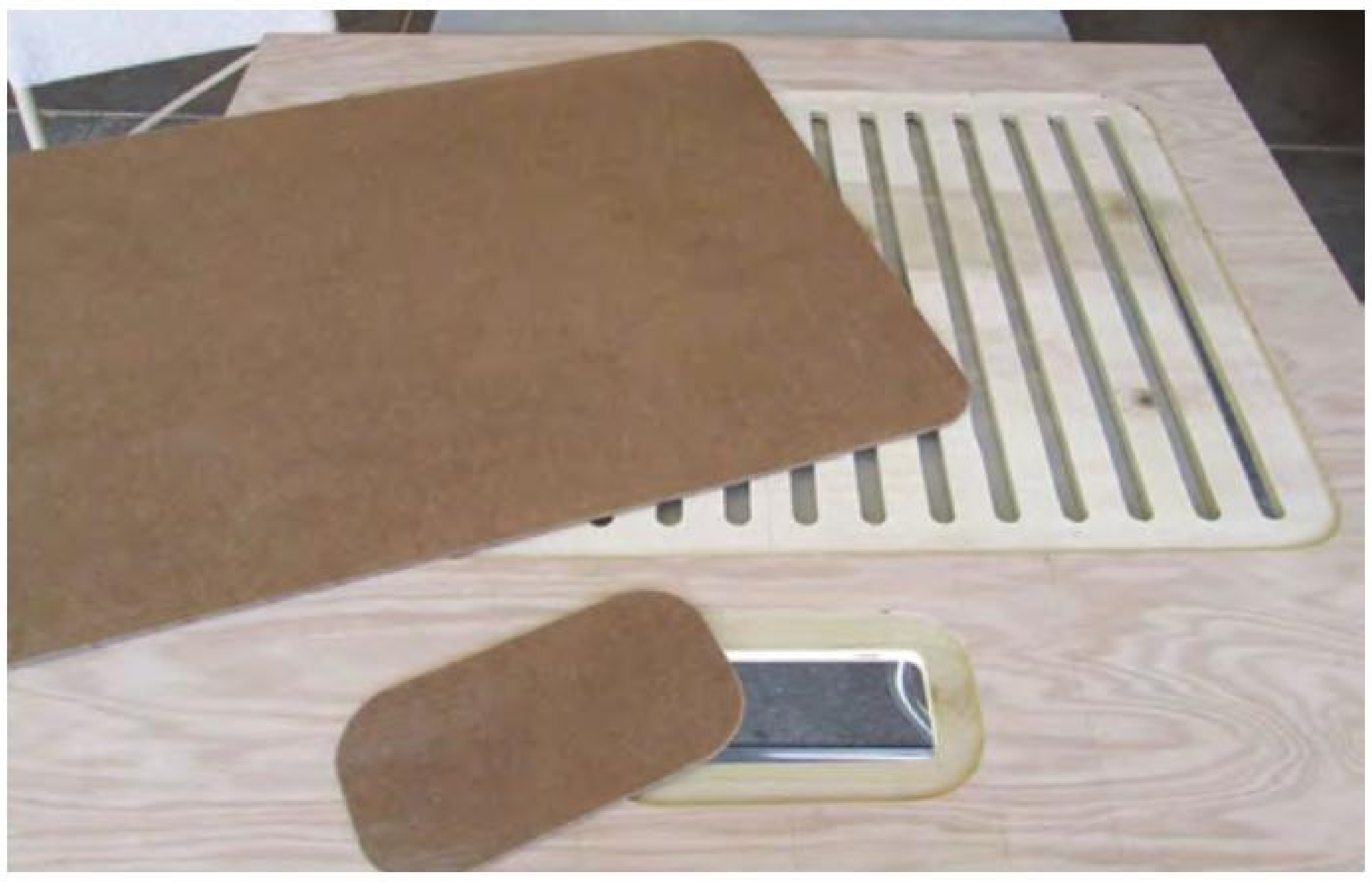

Fig.1. Main plywood front panel with the two hardboard sub-panels

Unfortunately, it's going to be about six weeks before they can start, because they are slammed with work. It's a strange setup really. Neither of their businesses, which are located in old warehouses, have any signage outside; nor do either of them have business cards or websites or anything like that. It's all done by 'word-of-mouth' and they have more work than they can handle. Philip wrote their contact details on a piece of paper and told me that now 'I'm a member of the secret club.'

I'll be posting pictures of the finished cabinet when… it's finished. But that's not what I wanted to tell you about. When it comes to the electronics, there are two main activities that have to be performed. One is to analyse the audio stream and extract its frequency data; the other is to take this data and present it on the display.

Arduino control

In the case of presenting data on the display, I opted to use an 8-bit, 16MHz Arduino Mega microcontroller (MCU) development board (**http://bit.ly/1gEbS2r**). The main reason for this choice is that Adafruit, the supplier of the NeoPixel Strips, provides an Arduino library to drive the strips, but this library only works with 16MHz Arduino Unos or Megas. One slight niggle with this solution is that, when the Arduino is uploading data to the NeoPixels, its interrupts are disabled and it isn't capable of doing anything else.

There are lots of different alternatives here, but the option I went for is to have a second device whose task it is to extract the frequency data from the audio stream. This second device could be an FPGA or an MCU. As a first pass, I decided to use a 32-bit, 80MHz chipKIT Max32 MCU prototyping platform (**http://bit.ly/1uf8Tnr**). Why? Well, first because it's got the same footprint – and uses an almost identical IDE – to the Arduino Mega. And second, because I happened to have one laying around in my office.

Digital signal processing

In the fullness of time, I plan on running a software algorithm like an FFT (fast Fourier transform), DFT (discrete Fourier transform), or DCT (discrete cosine transform) on the chipKIT MAX32. The advantage of using some form of digital signal processing (DSP) like this is that you can do all sorts of cunning data manipulation. The disadvantage is that I don't have a clue what I'm doing (but that never stopped me before).

I'm also going to implement my own simple handshaking protocol for communication between the chipKIT and the Arduino, but that's a trivial matter. The main point here is that once the Arduino has finished updating the display, it will raise a flag saying it awaits new data. Meanwhile, when the chipKIT finishes performing its current cycle of calculations, it will look at the flag from the Arduino. If the flag is active, the

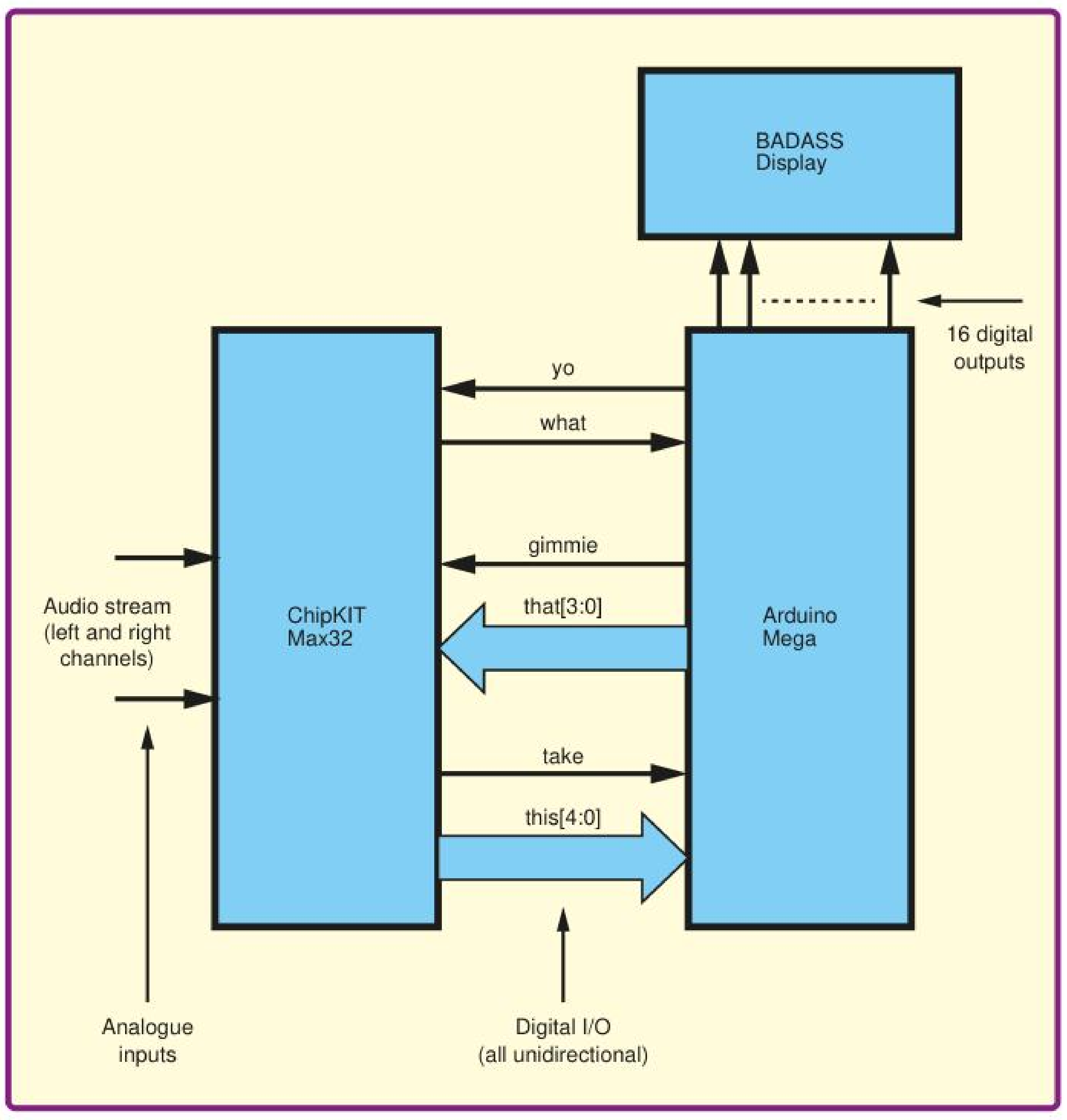

Fig.2. The chipKIT will extract the frequency data while the Arduino will drive the display

chipKIT will hand over its current data values; if the flag is inactive, the chipKIT will shrug its metaphorical shoulders, re-sample the audio data, and start a new cycle of calculations.

Having made all of these decisions, someone introduced me to a cunning little chip called the MSGEQ7, which is available for only $4.95 from the chaps and chappesses at SparkFun (**http://bit.ly/1jRKv3C**). This little scamp divides the audio spectrum into seven bands: 63Hz, 160Hz, 400Hz, 1kHz, 2.5kHz, 6.25kHz, and 16kHz, and it works out the magnitude (amplitude) of each band.

Clever chip

I've purchased two of these little beauties – one for each audio channel. Over the years, I've discovered that it's best to break a larger problem down into a series of smaller problems. My plan is to first use the MSGEQ7 chips to process the audio data and get the chipKIT to access the results and display them locally on LEDs using pulse-width modulation (PWM). At the same time, I can be playing with the Arduino, experimenting with simple routines to drive the display. Next, I'll get the chipKIT to hand the results from the MSGEQ7 chips over to the Arduino, which will present this data to the main display. Finally, I'll discard the MSGEQ7 chips and start to perform DSP inside the chipKIT.

There's so much more to talk about, such as the fact that you could do all this stuff using a PSoC from Cypress Semiconductor or a $20 Teensy 3.1 from PJRC.com, but these are topics for a future column. Until next time, have a good one!

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The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

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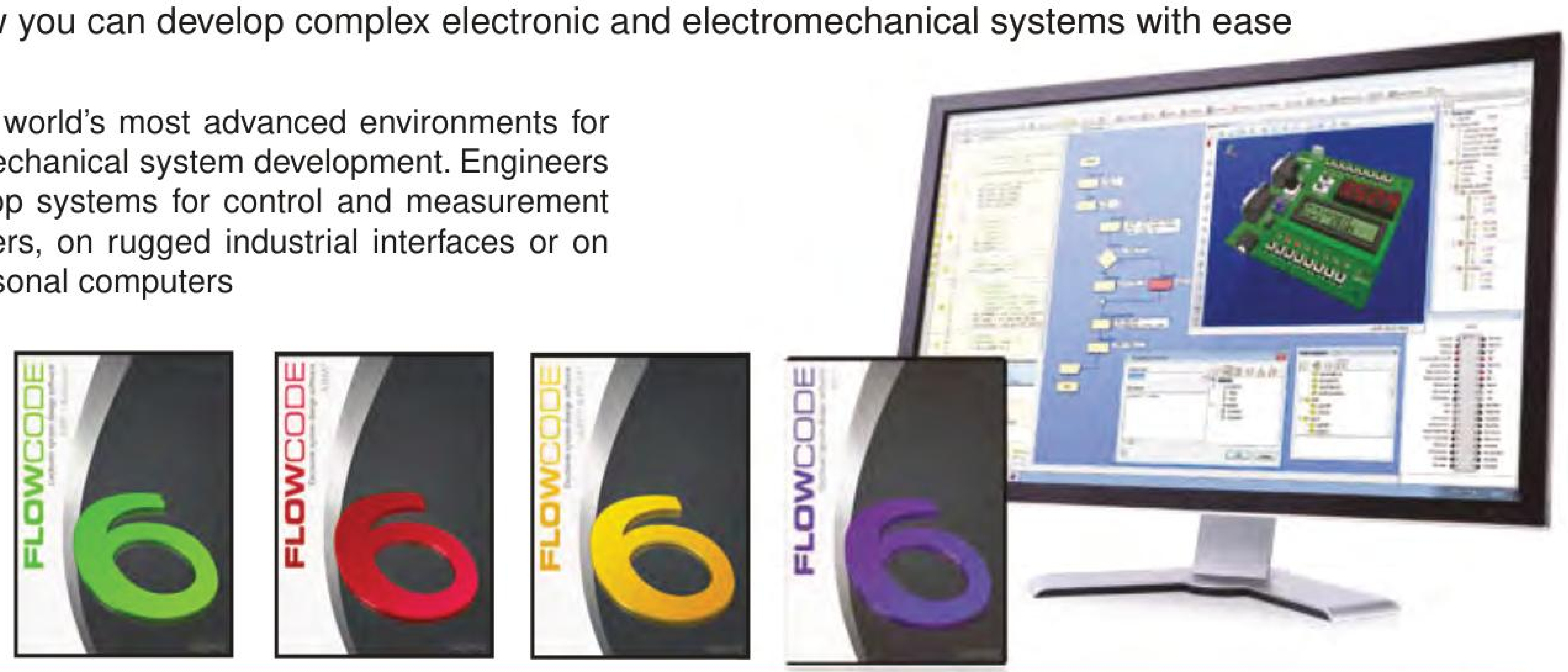

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This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the MLoader utility that is free to download when you buy the multiprogrammer board. For those who want to learn, choose one or all of the packages below to use with the hardware.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
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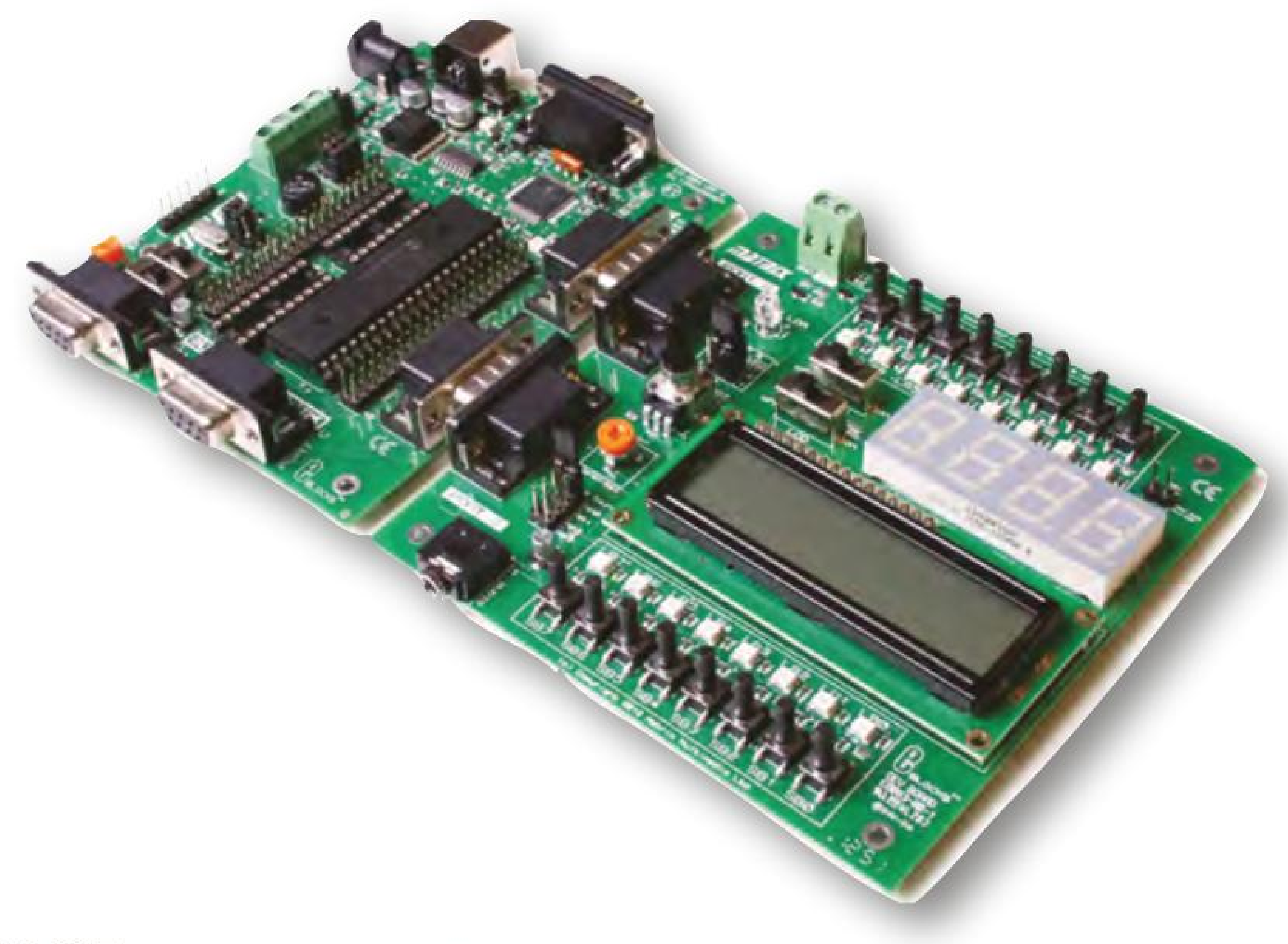


£167 including VAT and postage, supplied with USB cable and free to download programming software

SOFTWARE

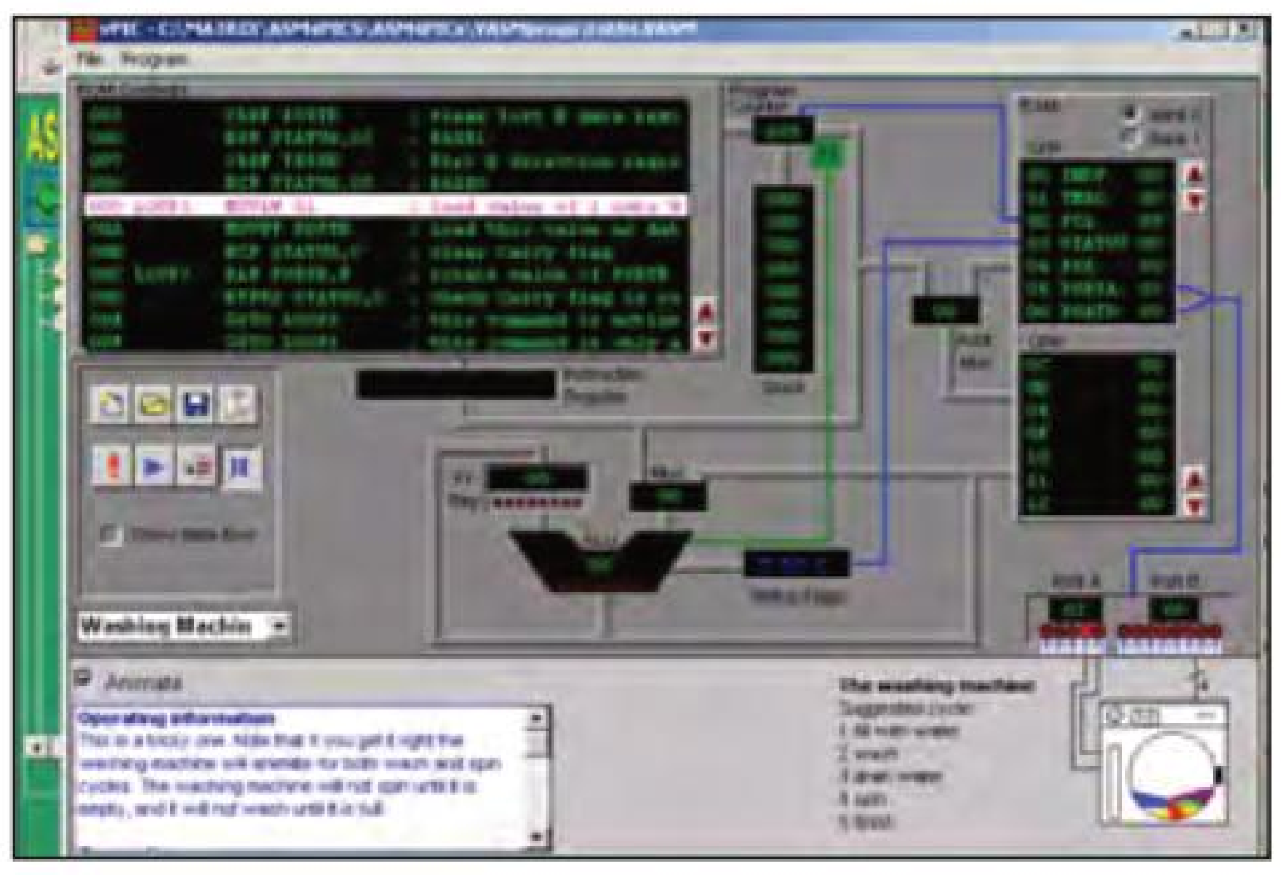
ASSEMBLY FOR PICmicro V5

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

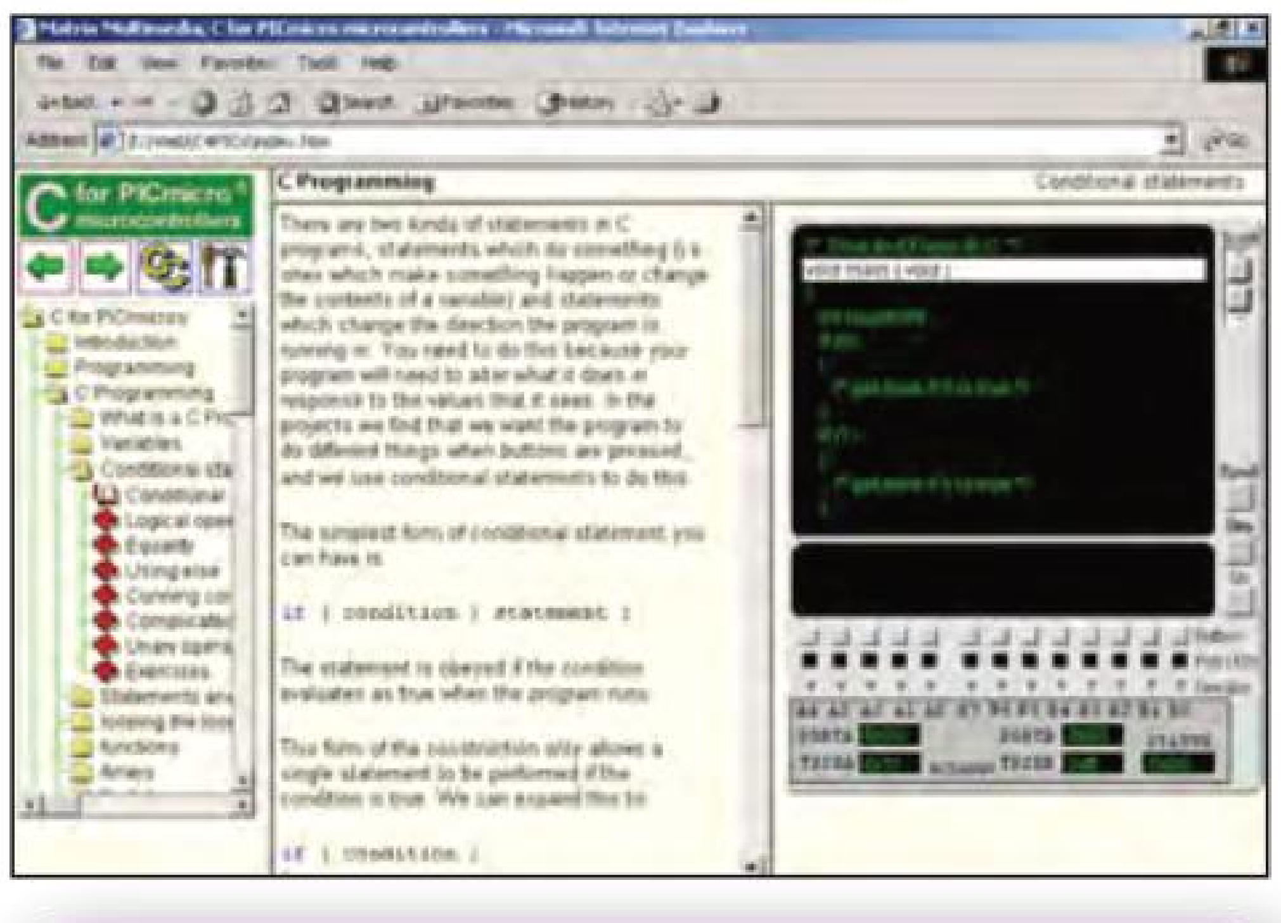


'C' FOR 16 Series PICmicro Version 5

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



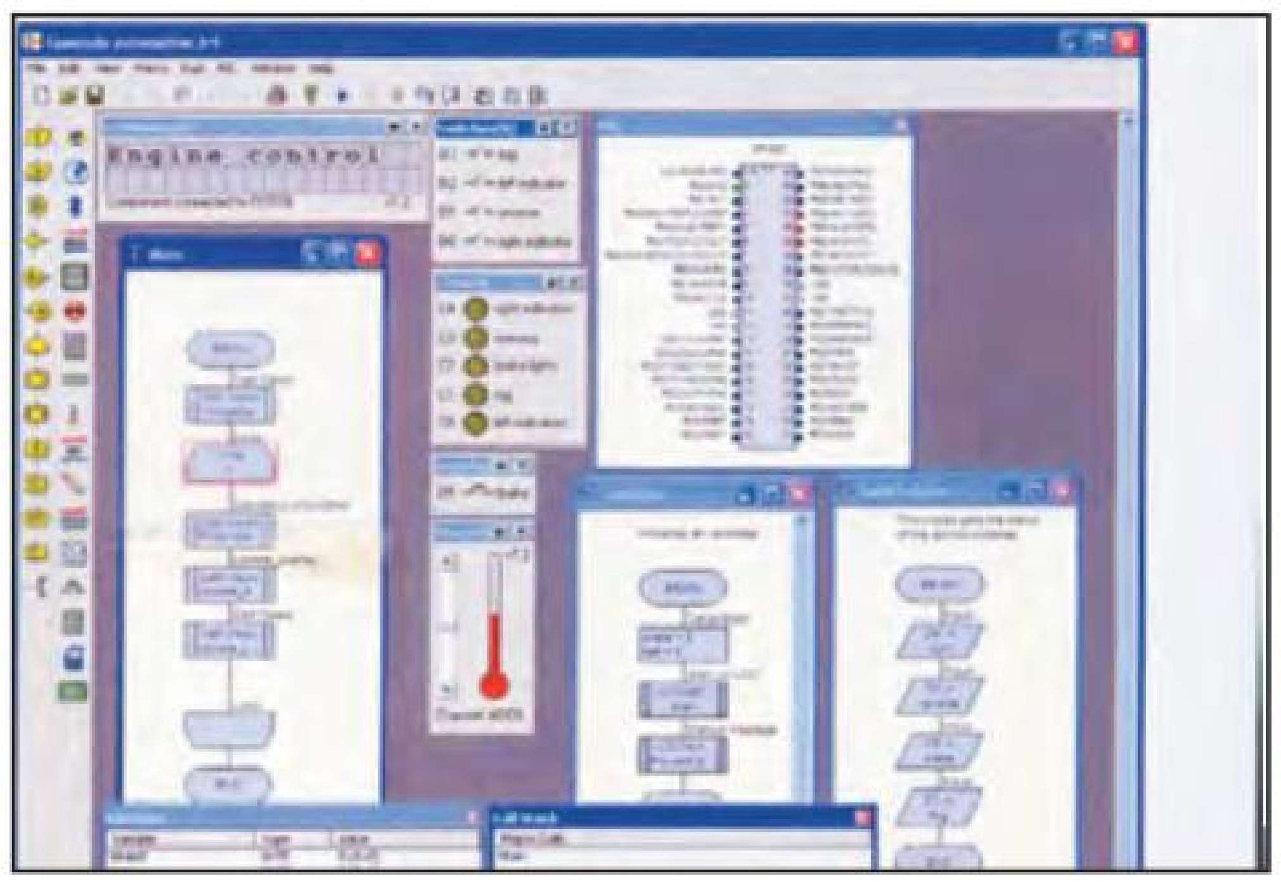
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6 (see opposite page)

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Features include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

See previous page for Flowcode Hobbyist/Student prices

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	**£58.80**	**inc VAT**
Professional (Schools/HE/FE/Industry)	**£150**	**plus VAT**
Professional 10 user (Network Licence)	**£499**	**plus VAT**
Site Licence	**£999**	**plus VAT**
Flowcode 10 user (Network Licence)	**POA**	**plus VAT**
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CIRCUIT WIZARD

Circuit Wizard is a revolutionary software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.
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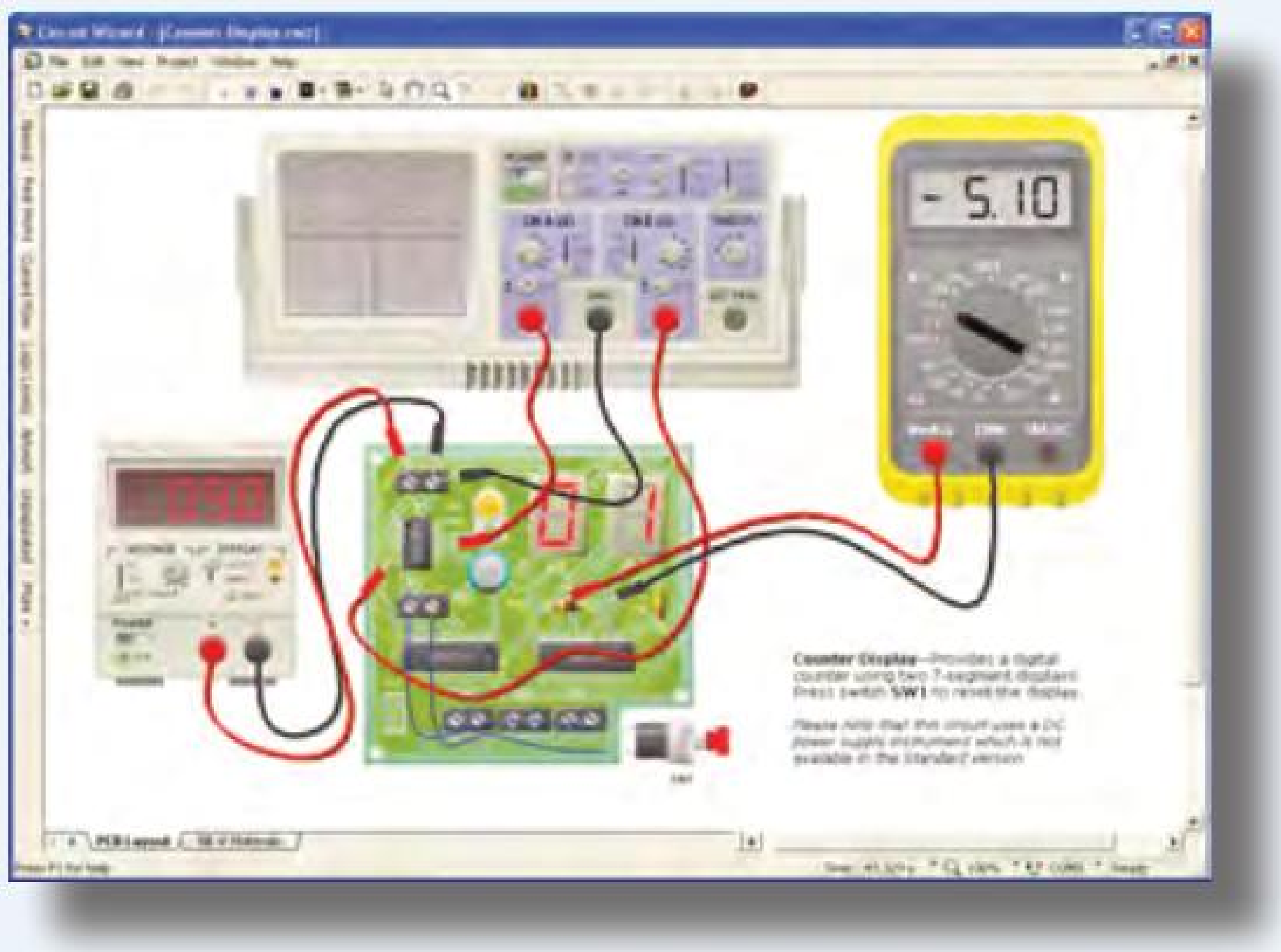

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT Professional **£91.90** inc. VAT

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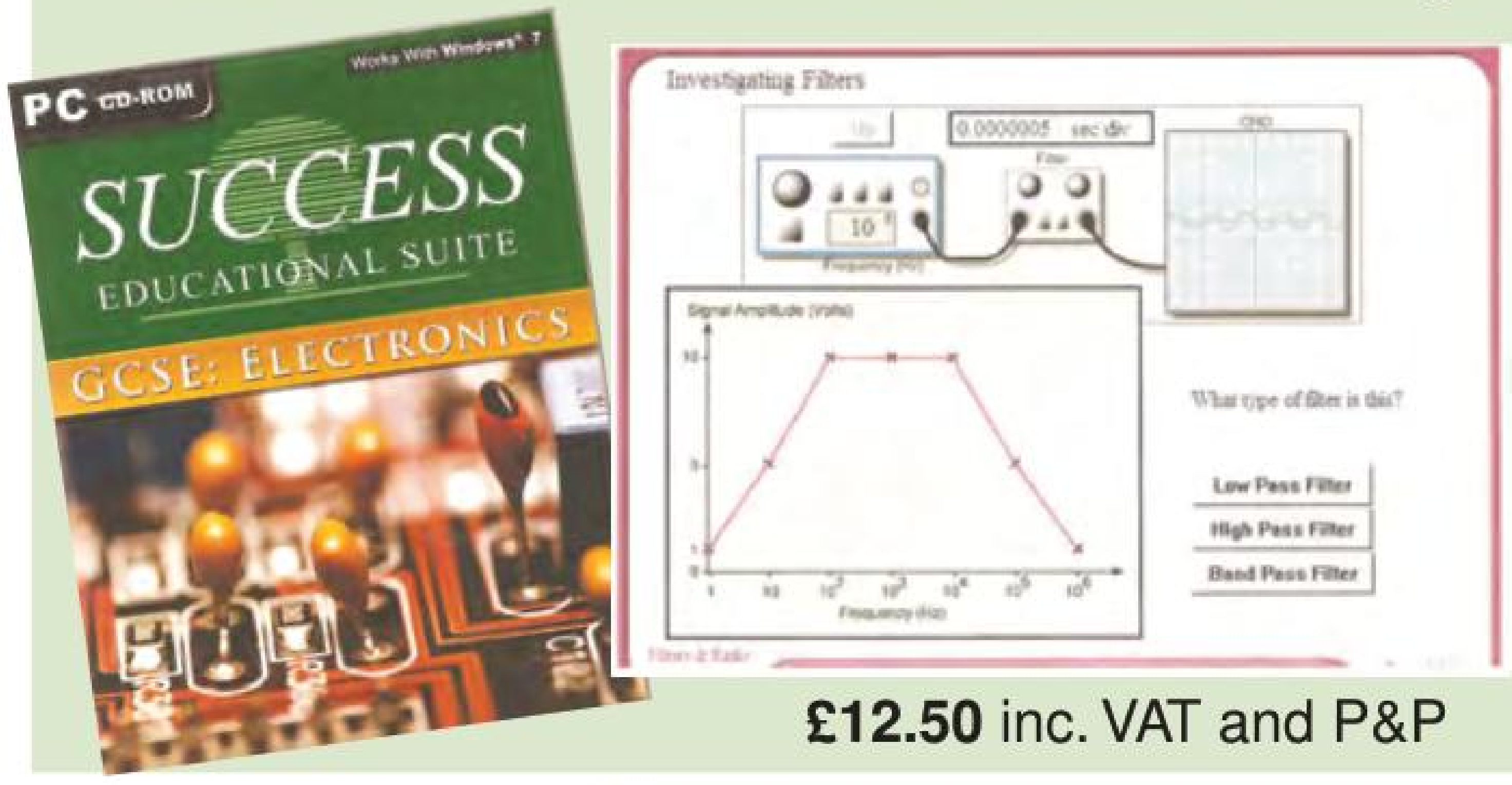

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Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

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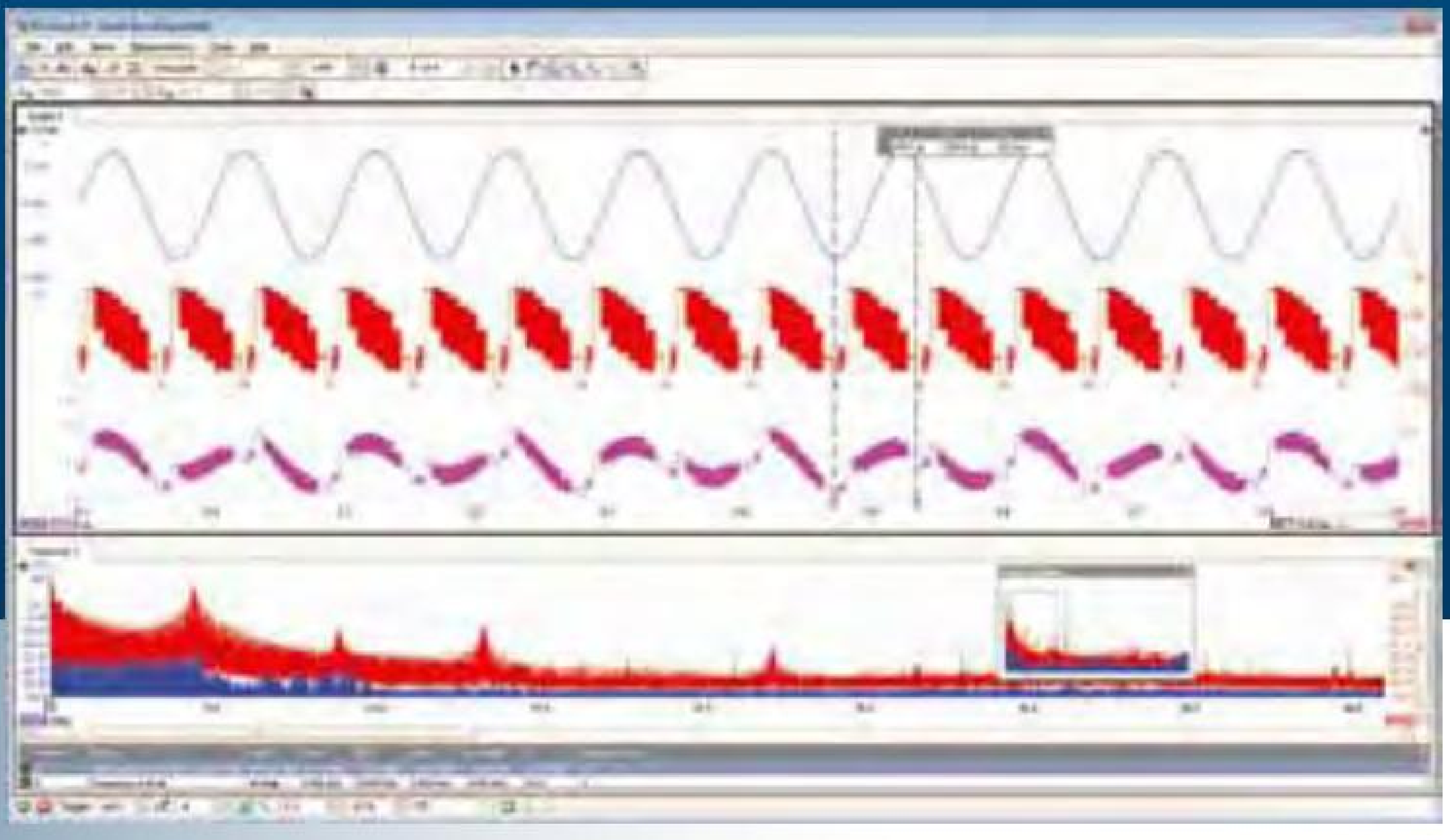

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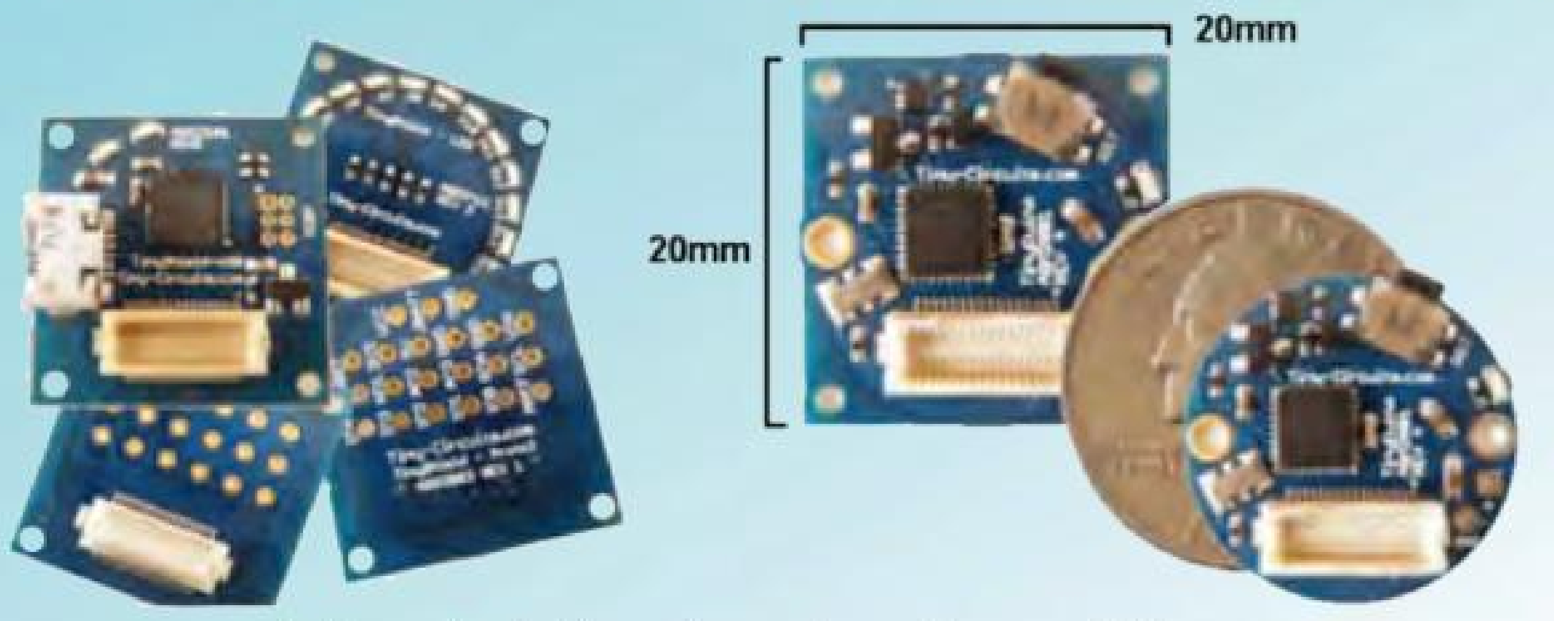

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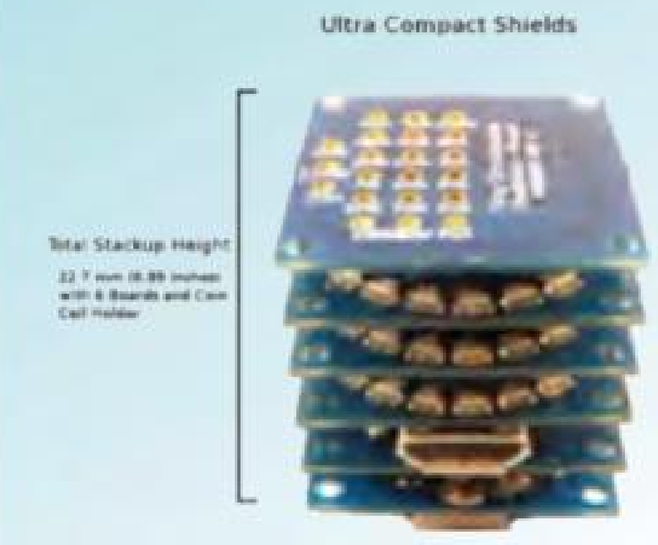

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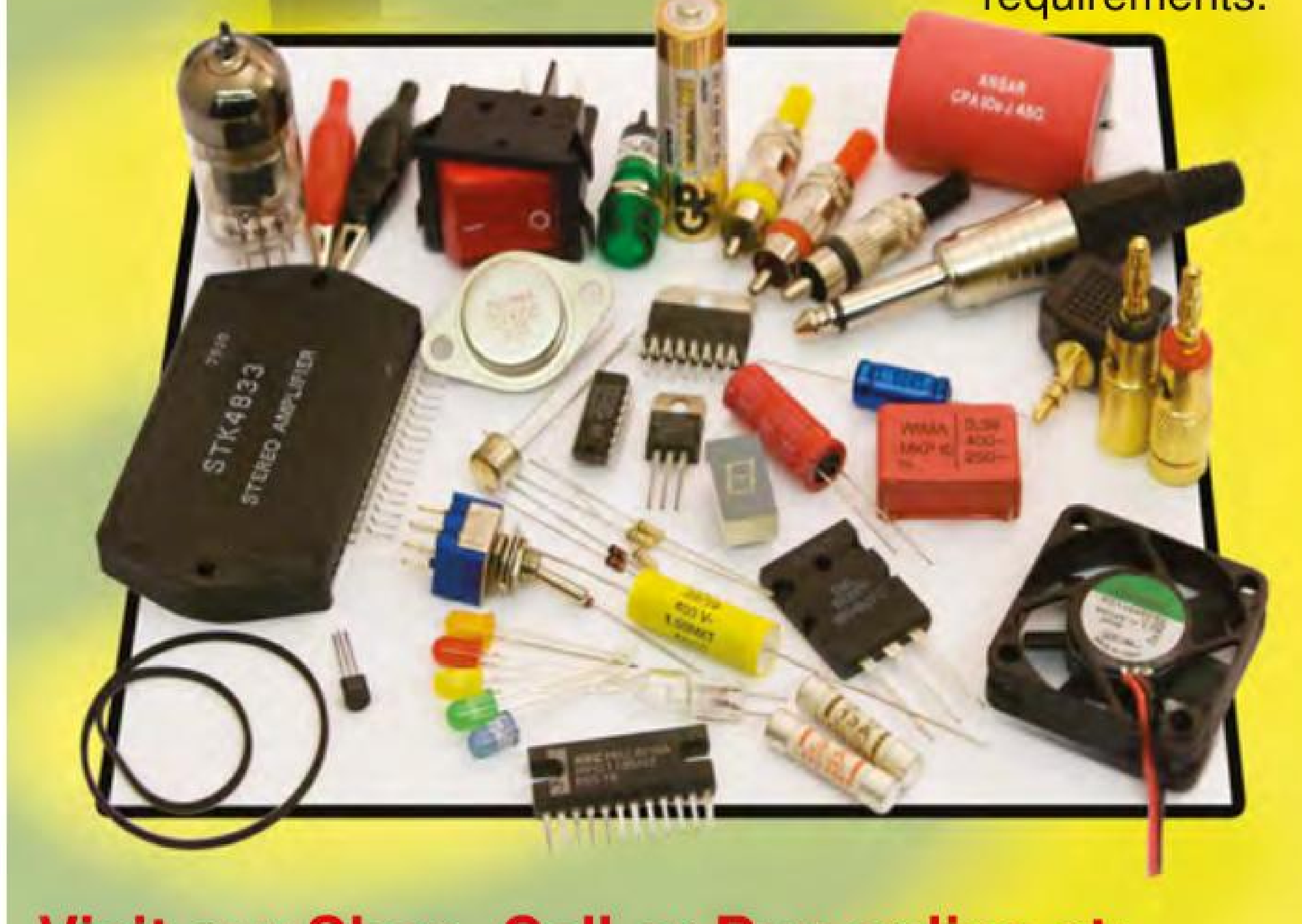

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NET WORK

by Alan Winstanley

No right to be forgotten

RECENTLY, Google came under the spotlight following a case in the European Court of Justice (ECJ), when a Spaniard won the legal right to demand that Google deletes from its database some web links that pointed to past events in his private life, claiming a breach of Article 8 of the European Convention on Human Rights (the right to a private life). The man was troubled by Google's numerous references to auction notices on his home dating back to 1998, and he had requested that these out-of-date search links be removed. Google refused and the ECJ waded into the row.

The result has been dubbed 'the right to forget' in the popular press, but in fact there is no automatic right to be forgotten at all. As Google once again stumbles into unknown territory, it has to weigh up the need to balance public interest and our right to know, against the obligation to protect a citizen's privacy. For any EU citizen wanting to exercise their supposed 'right to be forgotten' by Google, a simple online form recently appeared which is a hasty work-in-progress attempt as Google continues to thrash out the ramifications. The new online form is available at: **https://support.google.com/legal/contact/lr_eudpa?product=websearch**

Removing search engine links does not remove the original sources of data to begin with. It is also suggested that the deletion would only affect EU-based Google sites, and therefore the links may still be visible on non-EU websites. Beneficiaries of the supposed right for data removal might include convicts and bankrupts or anyone else wishing to suppress a dark chapter of their past. There are said to be thousands queuing up to have their personal history erased in this way, but after filling in the application form Google could decide to silently ignore it anyway, something I have experienced after filing some Google Local business review complaints.

Ultimately, it's the role of the Information Commissioner's Office and its EU counterparts, not Google, to oversee data protection rules and balance personal privacy against public interest. This latest development has a long way to go and it will be interesting to see how responsive and sincere Google decides to be.

A dead giveaway

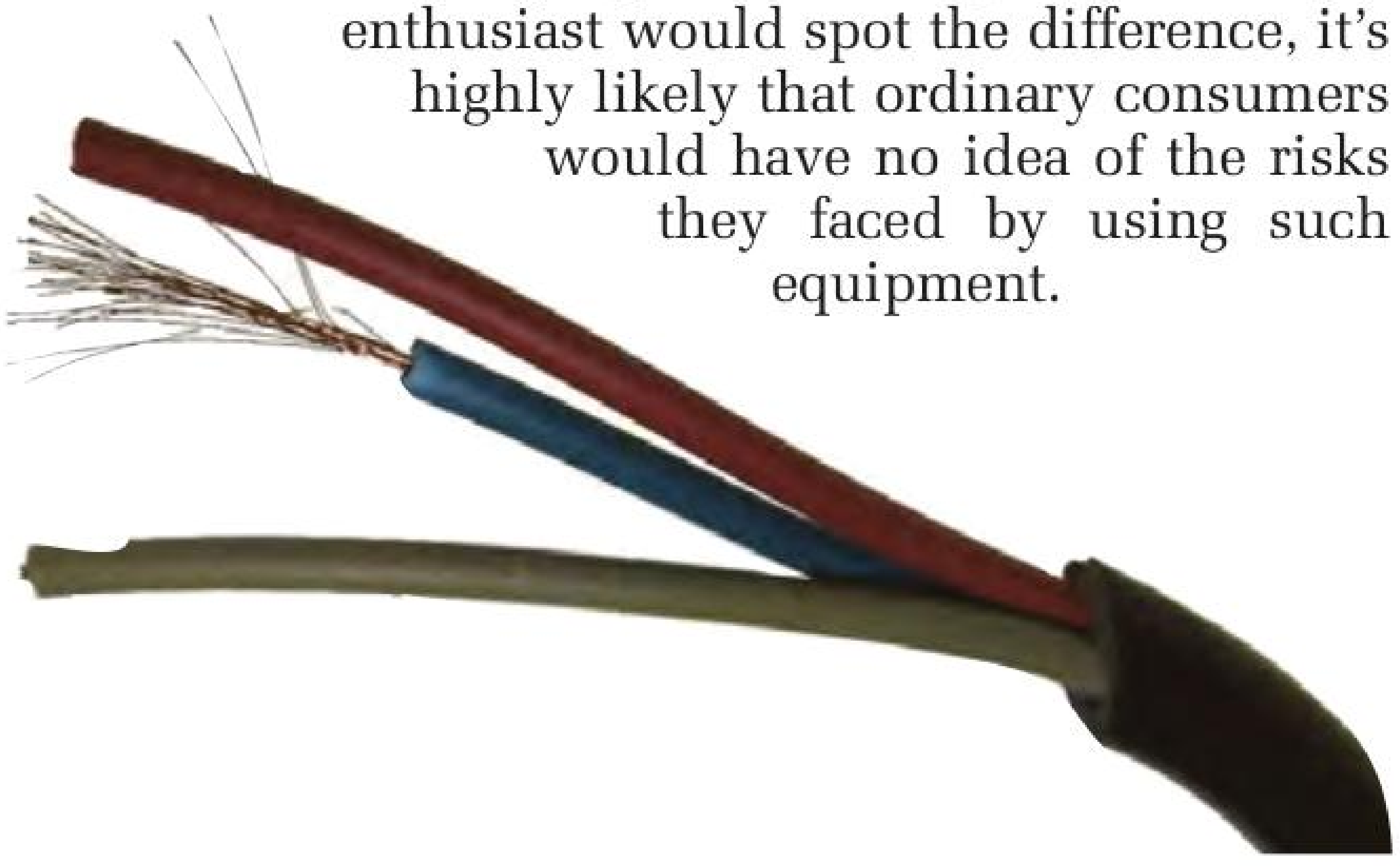
In decades past, to find a trade or industry supplier I would often thumb through a six-inch-thick directory such as *Kelly's*, a hefty slab of a book that landed with a thud on my desk each year. Orders were placed by fax or post. In today's era of e-commerce it is hard to believe that trade and industry somehow flourished by sending blizzards of paper everywhere. Nowadays, whether buying or selling, an entire marketplace of products and services is just a mouse-click away and the world has become much smaller as well; whether for business or personal use. It's now easy to shop around, compare prices and import directly from countless sources around the world just by searching and sourcing online.

The two most obvious online marketplaces are Amazon and eBay. These ubiquitous websites put buyers and sellers in touch with each other. Buyers place orders based on trust, user feedback and a general impression of 'look and feel'. In turn, sellers ship the goods hoping that they will not suffer a chargeback if the customer's credit card payment bounces a month or two later.

eBay is often the first port of call for countless domestic or electronics bits and pieces of every description, and some eBay sellers have earned positive ratings of several million transactions. eBay recently relaxed its rules and UK private sellers can now list up to twenty items a month without incurring listing fees, but PayPal fees must be factored in as well. The online auction house now skews the experience strongly in favour of the buyer, as without buyers no-one would use eBay. Buyers enjoy money-back guarantees and sellers are no longer able to leave negative feedback for troublesome customers: dealing with some buyers' histrionics over trivial matters can be exasperating, and sellers must also continue to earn high DSRs (Detailed Seller Ratings) to ensure sellers trade consistently.

Amazon's 'Marketplace' channel has also proved invaluable for helping countless independent traders to start selling online, with start-up costs from as little as £25 a month and commissions (depending on category) of typically 15-25 per cent retained by Amazon. Sellers receive net payments from Amazon on a rolling two-weekly basis. Like eBay, buyers using Amazon Marketplace can suffer from an inconsistent service, as Amazon Marketplace sellers are shipping direct to the customer; the writer has experienced everything from a terrific next-day service offered with pride, to truly awful experiences punctuated with chaos, misinformation or deceit.

Of course, Amazon Marketplace and eBay are simply facilitators for this trade and neither of them exercise direct control over the quality of merchandise. Some recent examples of mains-operated gadgets bought online revealed serious shortcomings in the quality of materials. In particular, some equipment was supplied with counterfeit UK mains leads or plugs, and although an electronics enthusiast would spot the difference, it's highly likely that ordinary consumers would have no idea of the risks they faced by using such equipment.


Sub-standard mains cable used on fake power cord with weak insulation and wrong colour codes

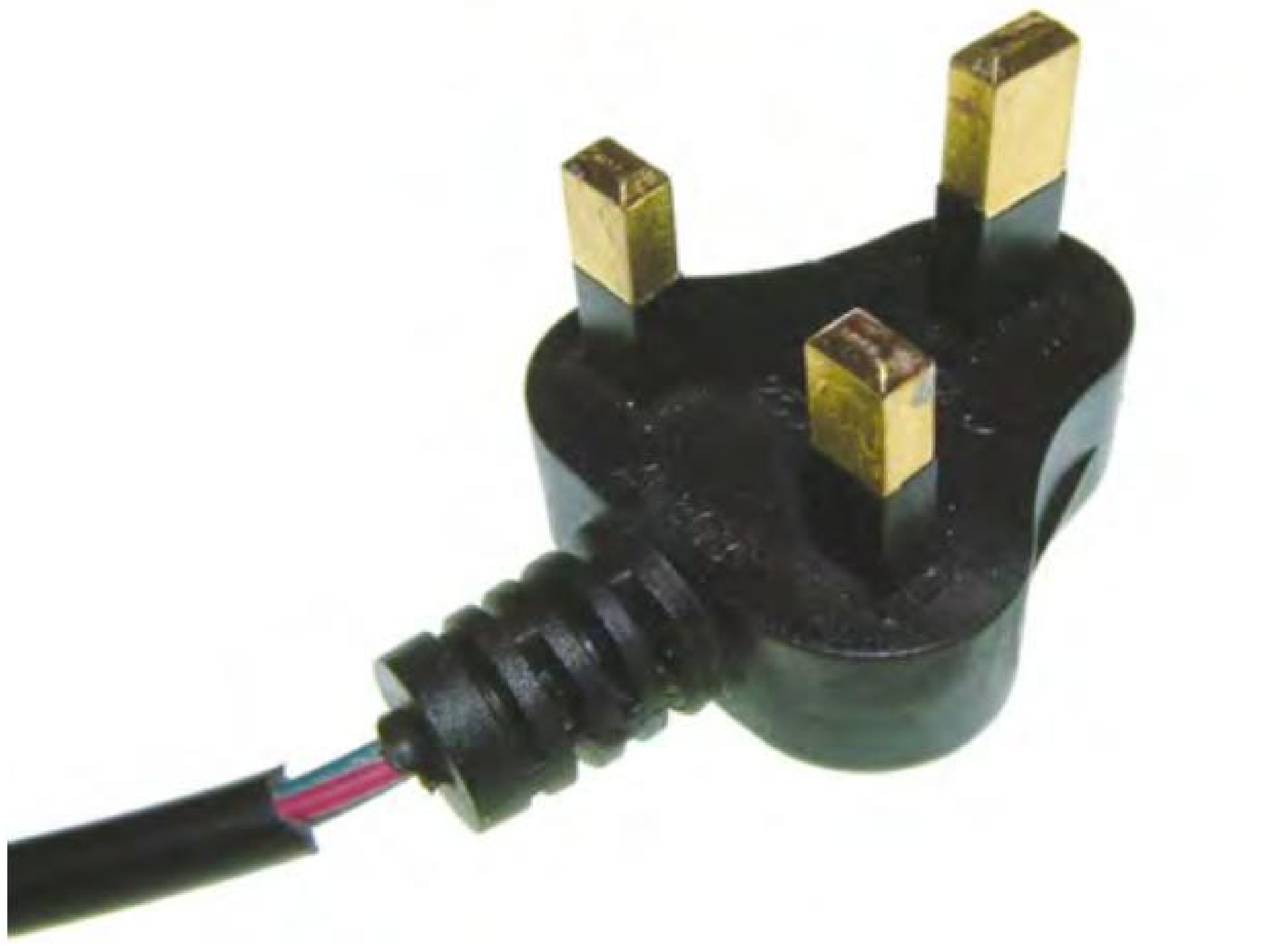
Horror stories

Due to the large volume of low-cost USB chargers and mains adaptors flooding into the country, both directly and through dodgy traders (who in turn source them online), there has been much coverage recently about the problem of fake mains chargers used for mobile phones or USB devices, with badly-made chargers exploding or reportedly causing serious house fires. Such devices can be sourced easily on auction websites, and as they literally cost pennies to manufacture they are produced to appalling standards at rock-bottom cost. Many products are unbranded and therefore untraceable, and they may suffer from serious faults including very poor insulation and poor assembly. The feeble plastic housing can break off in one's hand, leaving behind live mains circuitry clamped and exposed in the mains socket; they may also have poor soldering and fake CE or compliance logos. Although they may sport a standard USB socket, in some circumstances they are said to explode without warning, as some users of e-cigarettes and mobile phones have discovered.

Fake plugs

The British three-pin mains plug is both safe and robust, and has many virtues, including a built-in fuse and sleeved live and neutral pins. Readers may be interested in the *Digital Museum of Plugs and Sockets* at **http://famoud.nl/~plugsocket/Overview.html**, which showcases most major mains connectors from around the world. On a British mains plug, the larger earth pin connects before the supply voltage does, so the equipment is automatically earthed (grounded) first for safety. Compliant British mains plugs also state the relevant British Standard 'BS 1363/A' sign.

How badly can a mains power cord possibly be made? Some AA battery chargers were sourced via eBay and the quality of the mains power cords was truly appalling. Included were the most dangerous fake UK mains plugs I had ever seen, with hazards in every area. First, the moulded-on plug was simply too small so the pins could be grasped easily, risking electrocution when fingers curl underneath, and as another giveaway the earth pin was sleeved like the live and neutral pins were, so the equipment may not connect to ground very well, if at all.

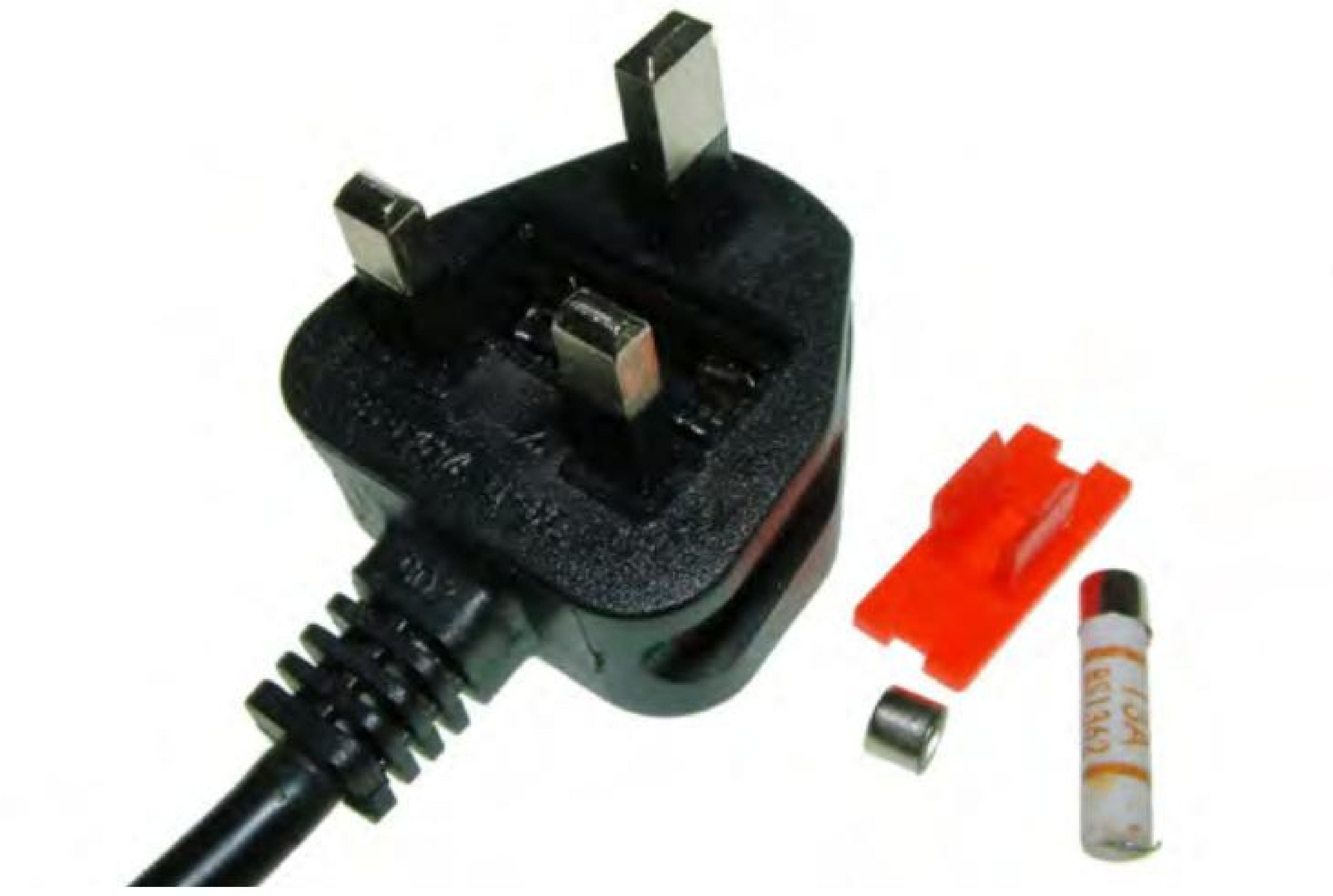


Fake mains plug with hazardous sleeved earth (ground) pin and strain relief/poor insulation faults. It's also not fused and too small (Photos: author)

More horrors were in store: the cable strain relief was so inflexible that the very weak cable insulation soon fractured at the point of entry, exposing the inner cores; the low-grade insulation was so poor that it easily peeled away between fingernails. Unsurprisingly, the counterfeit cable had the wrong colour codes and it was also unfused. We cannot tell what the conductors were made of, but the likelihood was that a copper-coated alloy was used. At the other 'figure-8' end of the power cord things were not much better. When faced with awful and potentially lethal products like these, the only thing to do is cut off the plug and throw everything away.

More recently, a popular SATA hard disk docking station sourced via an Amazon Marketplace vendor included an unbranded switched-mode power supply along with another fake mains lead. This time, the power cord was a very determined attempt to pass off a fake as a genuine BS 1363/A plug and it's a true shocker in every sense.

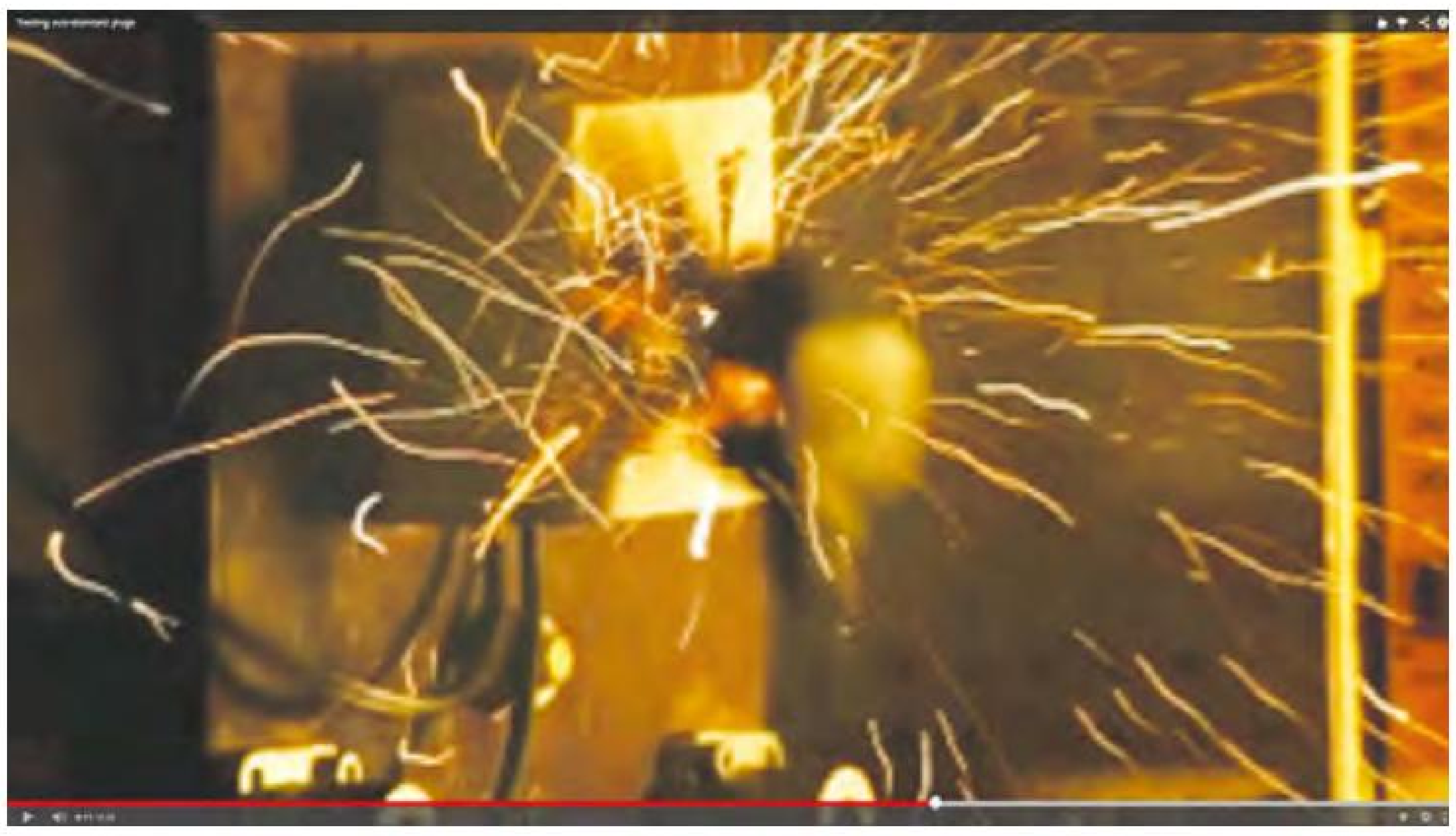
It had the same defect of using a sleeved earth pin, and it sported a phoney BSI 'Kitemark' approvals logo (see **www.kitemark.com**) and fake BS 1363/A marks moulded ino the body, along with a fake maker's logo. It claimed to be 'fused', but the counterfeit fuse had crimped-on metal caps and was not sand-filled to suppress arcing. The insulation was again very low-grade, and any kinks or cable damage could damage the insulation and possibly cause a fire. The colour codes were also wrong. I measured the cable's conductors with a micrometer and calculated that the so-called 10A cable is good for maybe a 60W light bulb at most. Once again, the entire product was unbranded and untraceable.



Another fake plug sourced from the Internet. It has a sleeved earth pin and fake British Standard fuse and markings

Help stamp out fakes

As explained on the volunteer website **www.bs1363.org.uk**, fake mains plugs such as these pose a very serious hazard and they could result in a house fire. How a typical fake plug may explode due to a fault is shown on YouTube at: **http://youtu.be/KVJVswLbqaA**



Counterfeit mains plug explodes out of the socket when overloaded (Electrical Safety First at Youtube)

Amazon is not alone in this problem, and it was simple to find on eBay dozens of similar USB 3.0 docking stations that included a fake UK mains power lead. Plugs with illegal sleeved earth pins are shown in images. The supply of counterfeit mains adaptors and chargers is an ongoing problem and the UK-based charity Electrical Safety First (**www.electricalsafetyfirst.org.uk**) highlights some examples and gives some sensible advice. They also list major recalls of electrical products in the UK.

I hope *EPE* readers can help to banish the scourge of fake power plugs and keep a wary eye open for any examples of counterfeit imported chargers, mains adaptors and phoney power leads – especially when you see less knowledgeable people using them.

You can email the author at **alan@epemag.demon.co.uk**

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Windows 8.1 is the latest version of Microsoft’s operating system. It is installed on all new Windows Desktop. Laptop and X86 tablet computers and is also available as a free upgrade. Whether you choose to use the touch screen Tile interface or the mouse operated Desktop interface, a good working knowledge of the operating system is essential to get the most from your computer and this book will help you to do just that.

The book applies to Windows 8.1, Windows 8.1 Pro and the vast majority of Windows 8.1 Enterprise. Also parts of the book should be applicable to windows RT 8.1 which is built on the same foundation as Windows 8.1 but is a restricted version designed specifically for ARM tablets.

Among the many topic covered are: An overview of the Tile Interface, Desktop, Taskbar, Tray Notification Area, Charms bar and running Apps; managing Windows settings, personalising your PC and creating User Accounts; using the Desktop File Explorer, SkyDive, Internet Explorer and the E-mail App; working with and organising digital photographs, using Media Player to play and store music and to burn CDs and installing Media Center to play DVDs; connecting to wireless networks, setting up a HomeGroup, sharing a printer and networked PCs; using mobility tools to keep your laptop running while away from home; accessibility features should you have dexterity or eyesight problems; keeping your computer healthy and backing up important files; And much more besides…..

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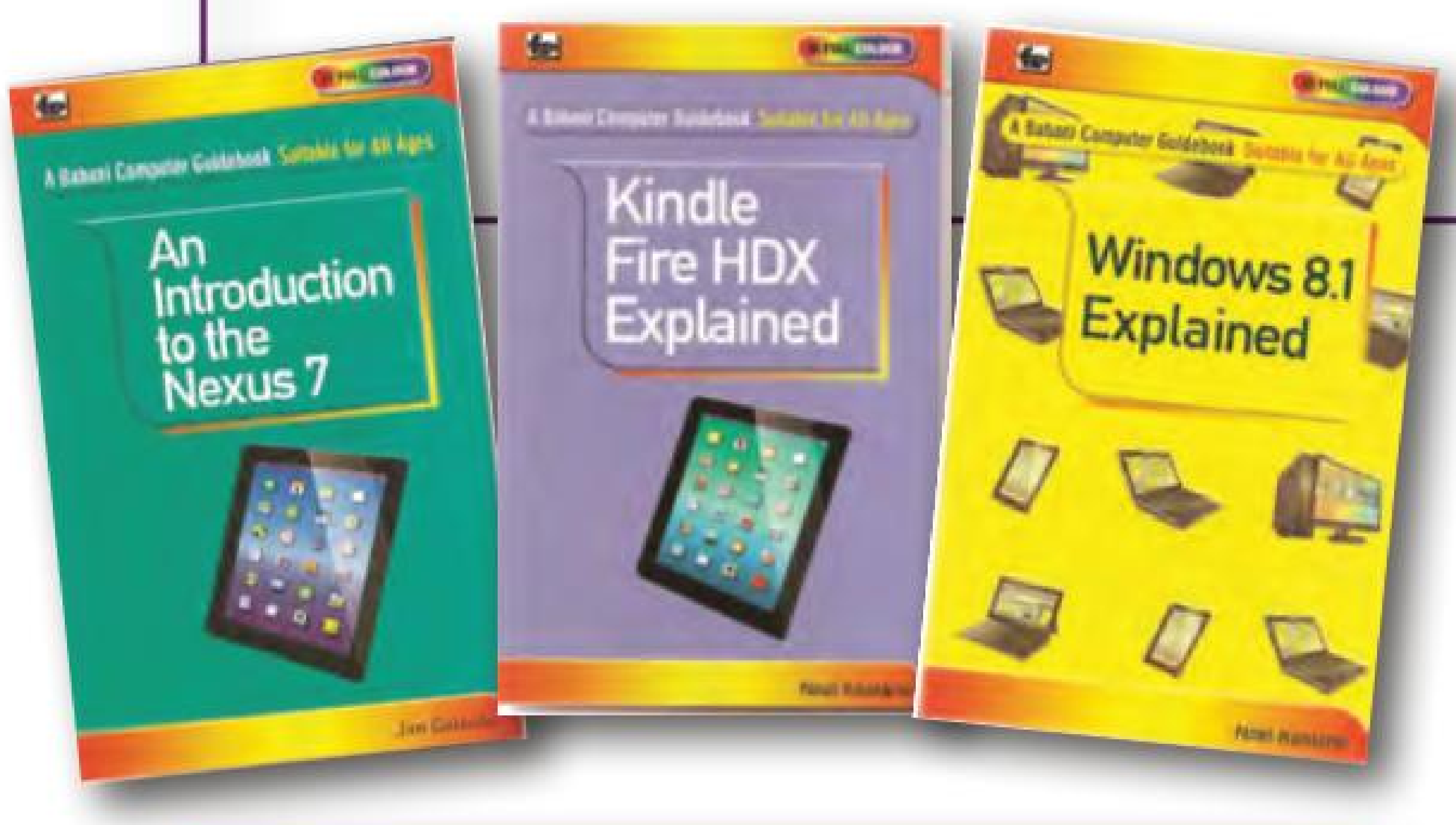
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An Introduction to the Nexus 7
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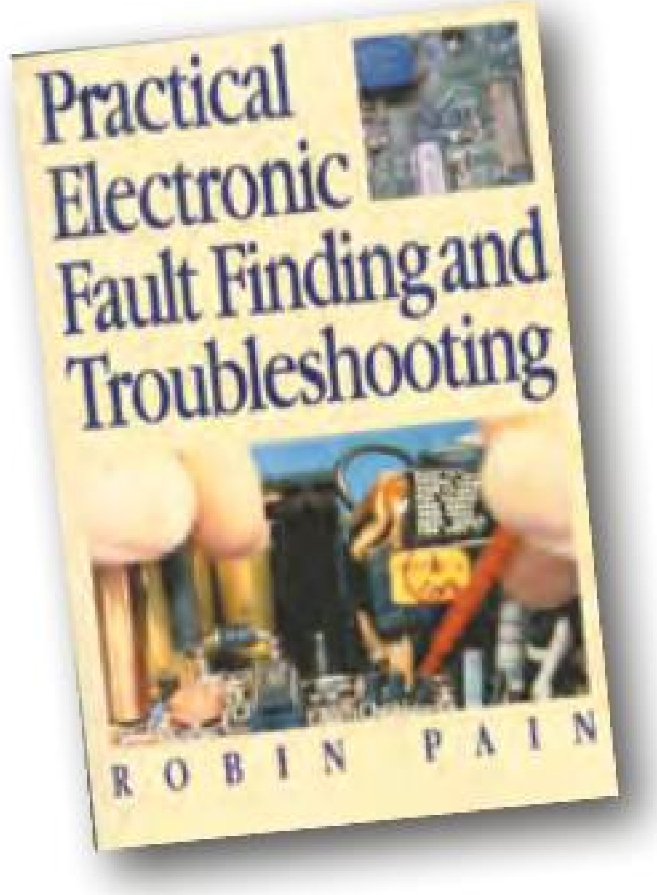

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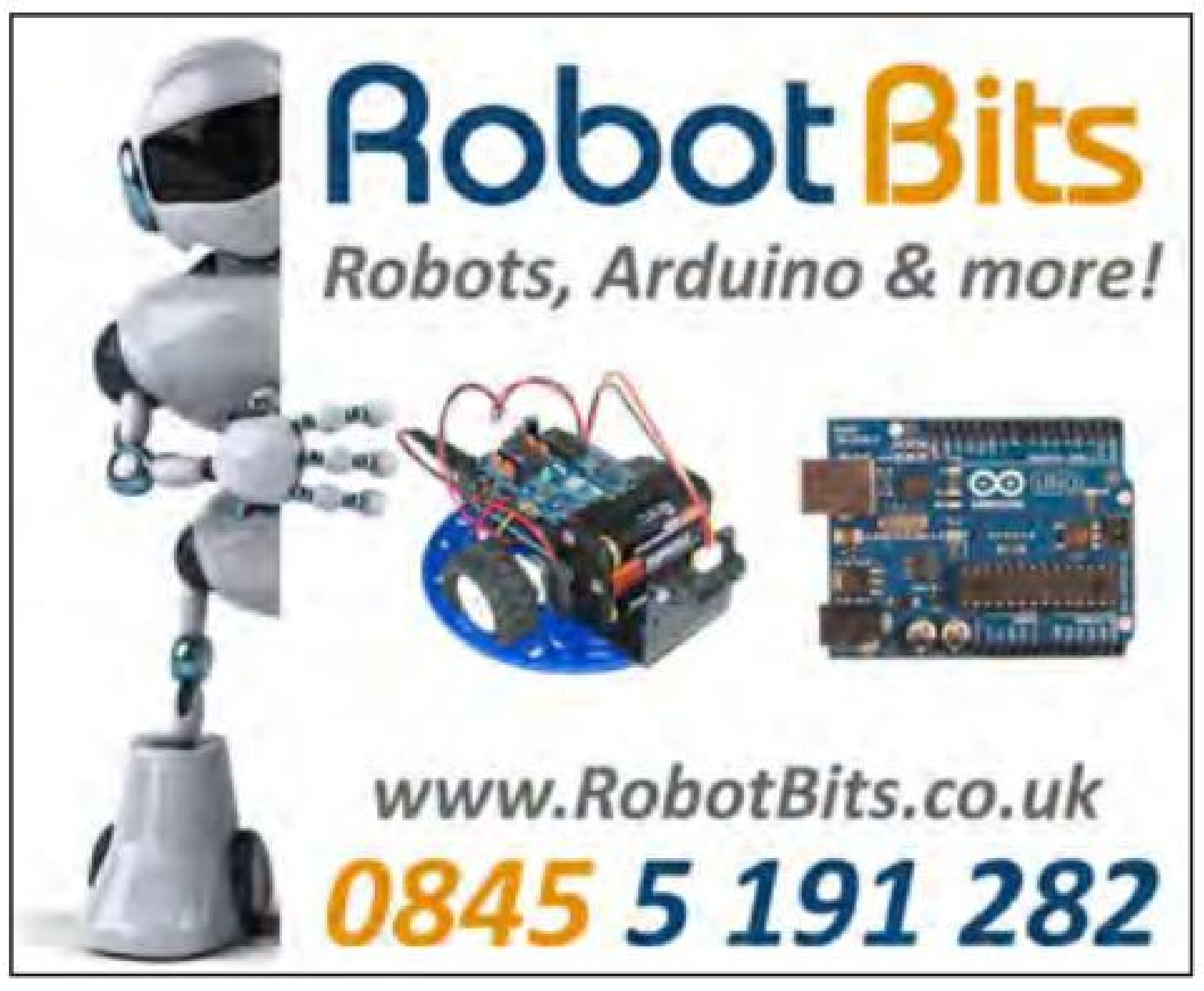

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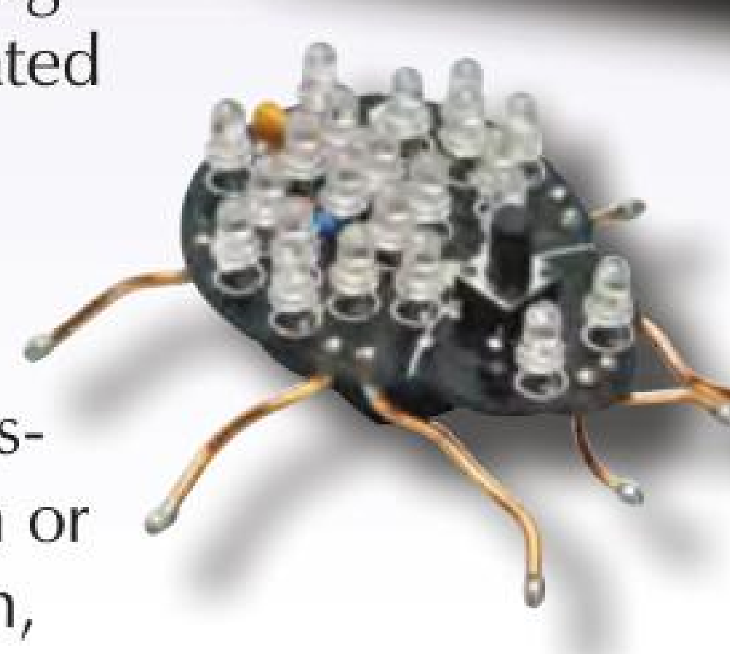

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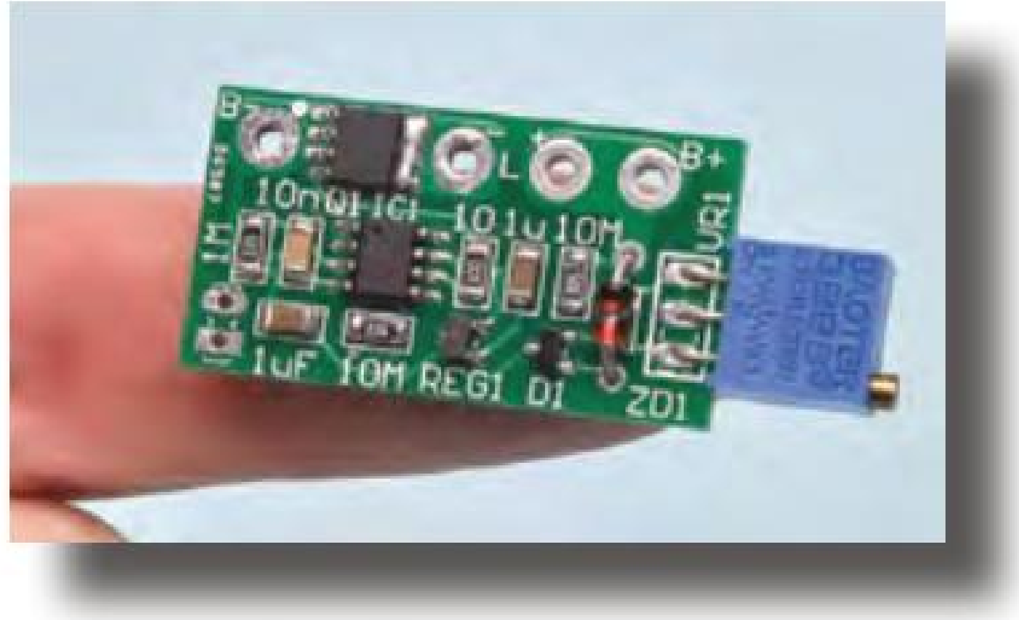

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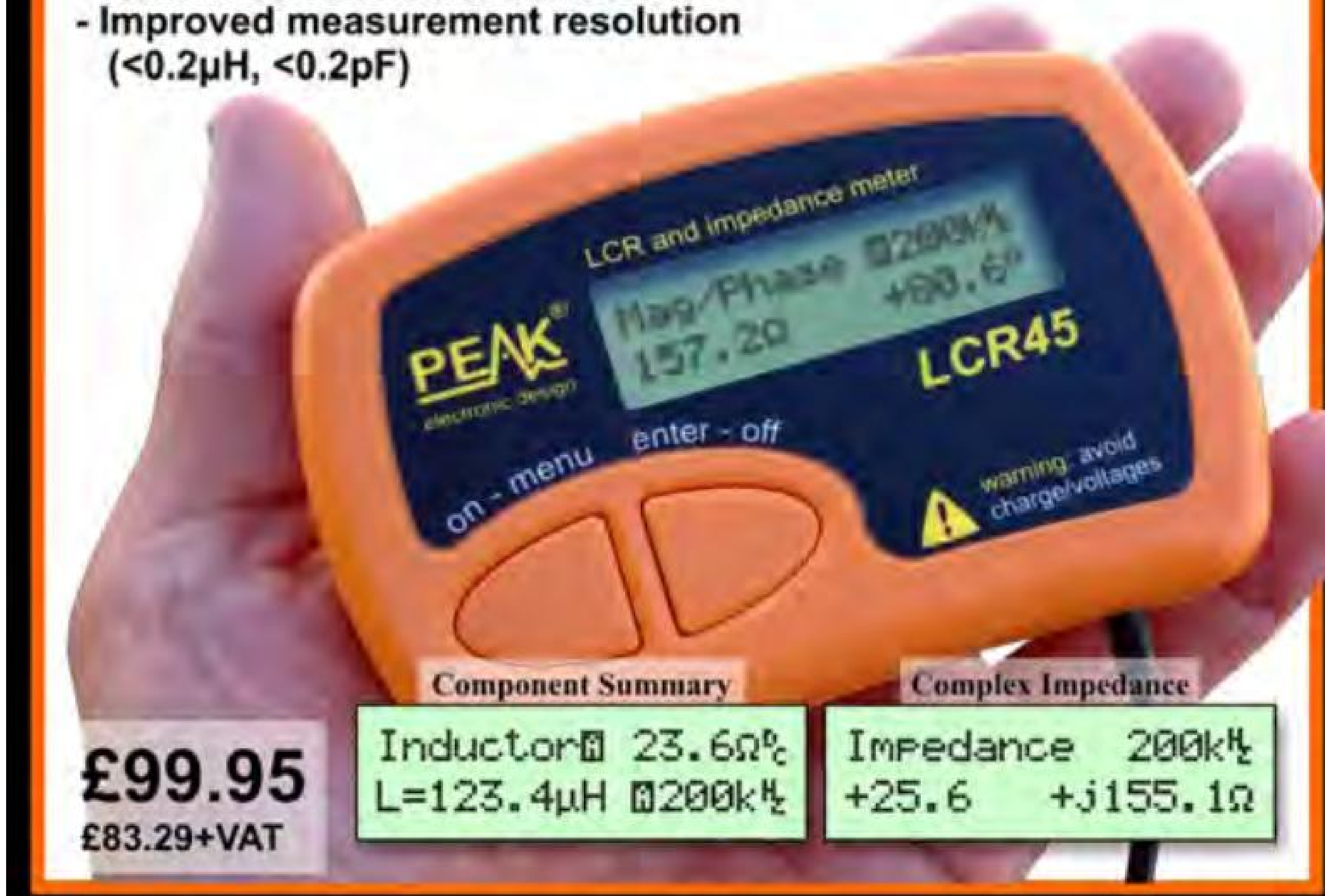

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